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Peat as a Fuel Source in Ontario:

A Preliminary Literature Review

Ontario

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A Preliminary Literature Review

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Executive Summary

Ontario's peat resources are extensive with approximately 16 million ha, accounting for 20% of Canada's total peat deposits (Monenco Ontario 1981), occurring primarily in remote areas in the Hudson/James Bay lowlands. Peat has been extracted for horticultural use and to a limited extent for use as a local heating fuel source (Daigle and Gautreau-Daigle 2001). In response to renewed interest in the potential of peat as a fuel source, we reviewed the literature to address key considerations of fuel peat extraction including the economic viability and associated socio-economic and environmental impacts. This review is a preliminary information-gathering exercise to aid in evaluating the potential for fuel peat extraction in Ontario and to inform related decision-making.

A number of excellent reviews have been published recently on peat extraction. They focus primarily on horticultural peat, but incorporate considerations for non-horticultural applications. Key themes include environmental impacts of extraction (Daigle and Gautreau-Daigle 2001, Mazerolle et al. 2001), carbon cycling assessments (McLaughlin 2004), greenhouse gas lifecycle analyses (Cleary et al. 2005), implications for the Kyoto Protocol (Roulet 2000), economic values (Woodward and Wui 2001, Lambert 2003, Olewiler 2004), regeneration and restoration (Robert et al. 1999, Daigle and Gautreau-Daigle 2001, Girard et al. 2002, Farrell and Doyle 2003, Quinty and Rochefort 2003), and hydrological management (Heathwaite 1994, Prevost and Plamondon 1999). This literature review complements these studies by highlighting common characteristics between horticultural and fuel peat applications, while emphasizing issues unique to larger-scale fuel peat extraction.

Based on the literature review, we found that a key issue associated with fuel peat extraction is the ongoing debate about the economic value of peat harvesting relative to the economic and ecological values of natural peatlands. While economic valuation of ecological functions, uses, and resources rarely occurs, science-based methods to do this are available. Here we attempt to inform the debate by defining the role of peatlands in both northern economic development and ecological sustainability.

Another issue that emerged from this review is that knowledge of and experience with wet mining extraction is minimal. Dry mining is most common for horticultural peat and involves sod cutting, vacuum extraction, or milled peat harvesting. This differs greatly from wet mining, which involves the removal of peat without on-site solar drying and transport to a plant for further dewatering and thermal drying. Whereas extensive research and experience with dry mining extraction is available, uncertainty exists about the environmental impacts and potential restoration approaches for wet mining.

Finally, this review clearly illustrates that significant terrestrial, hydrological, aquatic, and climatic impacts are associated with large-scale peat extraction and that these impacts are medium to long term. Peat extraction affects both the features and functions of a peatland (and larger wetland complexes), for example by reducing its size, decreasing biodiversity and species richness, affecting connectivity of wetland units, impairing hydrological conditions, and changing the volume, turbidity, and chemistry of discharge. In addition, extraction of fuel-grade peat alters the carbon balance of peatland ecosystems, contributing to net increases in greenhouse gas emissions to the atmosphere.

Résumé exécutif

Les ressources de l'Ontario en tourbe sont immenses et couvrent environ 16 millions d'hectares, ce qui représente 20 % du total des dépôts de tourbe du Canada (Monenco Ontario 1981), que l'on retrouve principalement dans les régions éloignées des basses terres des baies Hudson et James. On extrait la tourbe pour les besoins de l'horticulture et, dans une moindre mesure, pour servir de combustible pour le chauffage ménager local (Daigle et Gautreau-Daigle 2001). En réponse au regain d'intérêt pour le potentiel de la tourbe comme source de combustible, nous avons effectué une analyse documentaire pour aborder les principaux facteurs comme la viabilité économique et les répercussions socio-économiques et environnementales de l'extraction de la tourbe pour le chauffage. Cet examen est une collecte de l'information préliminaire qui a pour but d'évaluer le potentiel d'extraction de tourbe de chauffage en Ontario et d'éclairer les décisions qui seront prises à ce sujet.

On a récemment publié plusieurs excellentes études sur l'extraction de la tourbe. Elles se concentrent surtout sur l'extraction de la tourbe à des fins horticoles, mais prennent aussi en compte les applications non horticoles. Les principaux thèmes comprennent les répercussions de l'extraction sur l'environnement (Daigle et Gautreau-Daigle 2001, Mazerolle et coll. 2001), évaluations du cycle du carbone (McLaughlin 2004), analyses du cycle de vie des gaz à effet de serre (Cleary et coll. 2005), implications pour le Protocole de Kyoto (Roulet 2000), valeurs économiques (Woodward et Wui 2001, Lambert 2003, Olewiler 2004), régénération et restauration (Robert et coll. 1999, Daigle et Gautreau-Daigle 2001, Girard et coll. 2002, Farrell et Doyle 2003, Quinty et Rochefort 2003), et la gestion hydrologique (Heathwaite 1994, Prevost et Plamondon 1999). La présente analyse documentaire complète ces études en mettant en lumière les caractéristiques communes aux applications horticoles et aux applications de chauffage, tout en mettant l'accent sur les enjeux particuliers à l'extraction à grande échelle de tourbe pour le chauffage.

En nous fondant sur cet examen documentaire, nous avons trouvé que le débat actuel sur la valeur économique de l'extraction de tourbe par rapport aux valeurs économiques et écologiques des tourbières naturelles est un enjeu majeur pour l'extraction de tourbe destinée au chauffage. Même s'il est rare que les fonctions, utilisations et ressources fassent l'objet d'une évaluation économique, il existe des méthodes scientifiques pour le faire. Nous essayons ici de fournir des arguments au débat en définissant le rôle des tourbières dans le développement économique et aussi dans la durabilité écologique des régions du nord.

Une autre question soulevée par cette analyse est que les connaissances et l'expérience sur l'extraction dans des conditions humides sont minimes. L'extraction après drainage est la plus courante pour la tourbe horticole; cela comprend le découpage de blocs de tourbe et d'aspiration sous vide, ou la récolte de tourbe broyée. Cela change beaucoup de l'extraction dans des conditions humides; la tourbe, extraite sans séchage solaire sur place est transportée à une usine où elle sera déshydratée et séchée par des moyens thermiques. Bien qu'il y ait beaucoup de recherches effectuées sur l'extraction après drainage et que l'on ait beaucoup d'expérience dans ce domaine, nous sommes dans l'incertitude quant aux incidences environnementales de l'extraction dans des conditions humides et aux approches de restauration possibles après cette forme d'extraction.

Finalement, cette analyse démontre clairement que des répercussions terrestres, hydrologiques, aquatiques et climatiques significatives sont associées à l'extraction de tourbe à grande échelle et que ces répercussions dureront à moyen terme et à long terme. L'extraction de la tourbe touche à la fois les caractéristiques et les fonctions d'une tourbière (et des terres humides plus étendues), par exemple en diminuant sa taille, sa biodiversité et sa richesse en espèces, en affectant la connectivité des marécages entre eux, en modifiant les conditions hydrologiques et en changeant le volume, la turbidité et la composition chimique des eaux évacuées. De plus, l'extraction de tourbe combustible modifie le bilan de carbone dans l'écosystème des tourbières, et contribue à l'augmentation nette des émissions de gaz à effet de serre dans l'atmosphère.

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Contents

1. Background

Current interest in peat as a fuel source for electricity production can be linked directly to increases in the prices of conventional fuels, such as oil and natural gas, and planning for diversifying Ontario's supply mix. The Ontario government's target to eliminate coal-fired electricity generation by 2009 has advanced discussions of, for example, replacing coal with alternative fuel sources at the Atikokan Ontario Power Generation (OPG) Station, slated for closure in 2007.

One company, Peat Resources Ltd., has been involved in proposals to mine peat for use as a fuel since the late 1970s. Peat Resources Ltd. has explored and tested peatlands in the Ignace and Upsala areas and is now expressing interest in Atikokan. This company currently has 3 land use permits authorizing exploration on a total area of over 20,000 ha of peatlands in the Ontario Ministry of Natural Resources' (MNR) Thunder Bay District. They have applied for a land use permit for a similar-sized area around Ignace. The current exploration program is targeted at defining the quality and quantity of the local peat resource to determine whether it will support the development of a peat processing facility that would supply fuel-grade peat to the OPG coal-fired plants in Atikokan and Thunder Bay. Other organizations have also obtained permits to explore for peat in these areas.

Peat harvesting was highlighted as an issue in the Environmental Commissioner of Ontario's (ECO 2005) Annual Report for 2004-05. The report concludes that regulation of peat resources and harvesting activities is out of date and has gaps. In particular, peat extraction is specifically exempt from regulation under Ontario's *Mining Act* and *Aggregate Resources Act*. The Provincial Policy Statement (PPS) (Ministry of Municipal Affairs and Housing 2005) under Ontario's *Planning Act* prohibits development and site alteration in provincially significant (PS) wetlands in Ecoregions 5E, 6E, and 7E (Figure 1), and in all PS coastal wetlands (wetlands on the Great Lakes or their connecting channels). This unqualified prohibition does not extend to PS non-coastal wetlands in northwestern Ontario. Instead, in the Canadian Shield north of Ecoregions 5E, 6E, and 7E, development and site alteration are not permitted in PS and adjacent wetlands unless it can be demonstrated that no negative impacts on the natural features or their ecological functions will occur. However, the 2005 PPS does not specifically identify peat harvesting as a type of site alteration and ambiguity exists as to the scope of protection that municipalities are required to provide to peatlands because many bogs and areas containing peat resources are not designated as PS in official plans. The Environmental Commissioner of Ontario recommends that MNR, in consultation with other provincial ministries, develop appropriate regulations to ensure that peat harvesting is carried out with minimal ecosystem disturbance, and that appropriate rehabilitation is undertaken (ECO 2005).

Decisions under the *Planning Act* and those closely related to municipal planning must be consistent with the PPS. For other planning in which the MNR is involved, such as Crown land use planning, MNR may consider related policies or otherwise meet the intent of the PPS. Current MNR policy (LM 8.17.01 – *Peat and Peatland Disposition* and bulletin PL 4.14.00 – *Peat Exploration on Crown Land*) permits peat exploration and extraction, but provides limited direction for processing an application as large and complex as that being contemplated by Peat Resources Ltd. They submitted their initial development proposal for a large-scale extraction and processing operation in the Upsala area to MNR in August 2005 (see Appendix 1). The proposal was deemed inadequate for screening under the Class Environmental Assessment (EA) for Resource Stewardship and Facility Development Projects and was returned. A revised submission was received in October 2005 and referred to Ministry of Environment (MOE) for consideration as a candidate for an individual EA under the Environmental Assessment Act.

Another current activity relating to peat as a potential source of fuel is a feasibility study commissioned by the Ministry of Energy. The study examines the viability of a number of alternatives for sustainable exploitation of bio-energy resources in northwestern Ontario for electricity generation at Atikokan, including, but not limited to, the proposal by Peat Resources Ltd.

In addition to the study, the 2006 budget allocated $4 million in an effort to establish a bioenergy research centre in Atikoken.

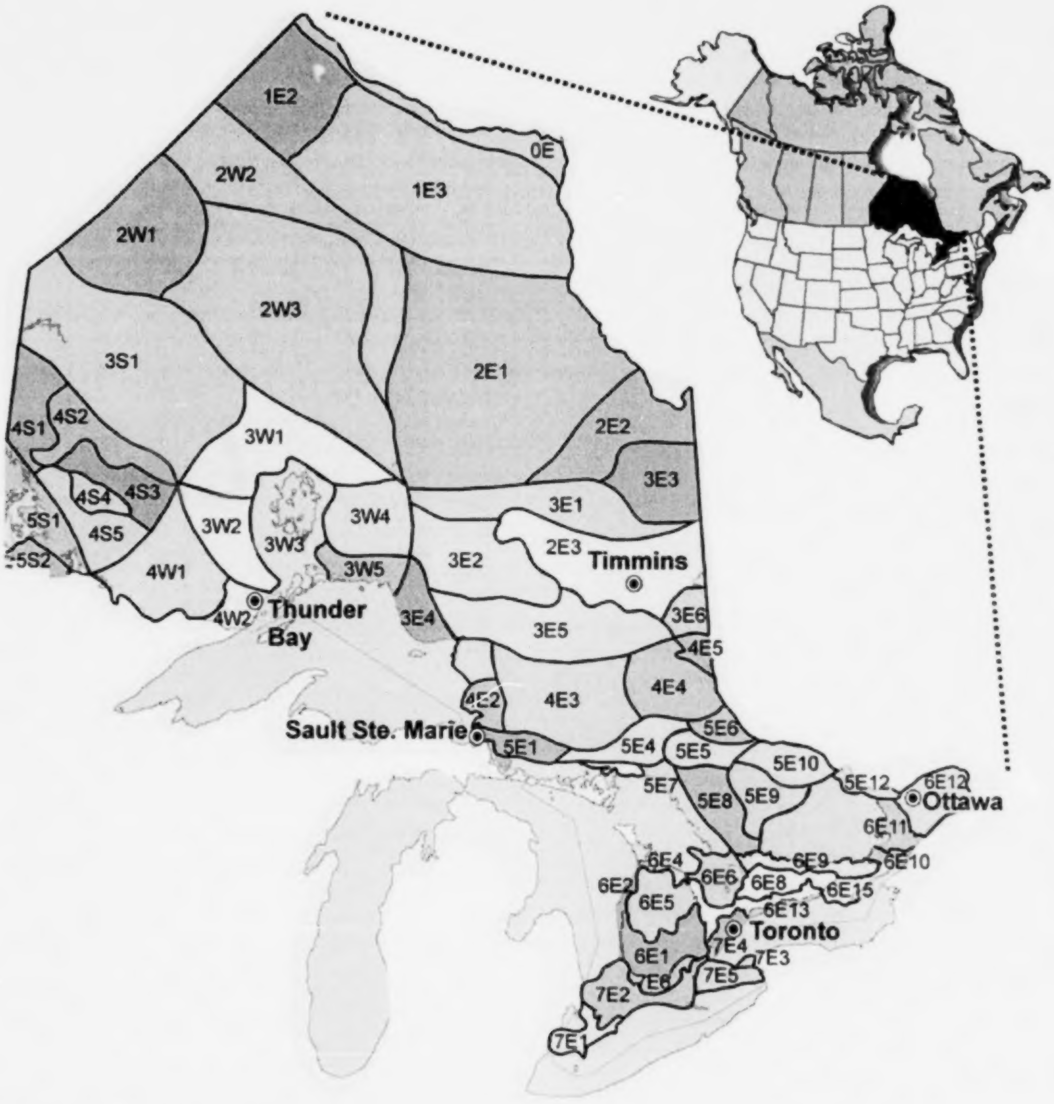

Figure 1. *Ecological site districts in Ontario.*

2. Peat as an Energy Source

a) Functions and Values of Peatlands

Peat is a biomass resource composed of a group of accumulated organic residues that slowly develop as a result of incomplete decomposition of plant debris in very moist and anaerobic conditions (Belanger and Dubois 1988). The net rate of peat accumulation depends upon factors such as water regime and temperature, but is estimated to be between 20 and 60 cm per 1000 years (Montanarella et al. 2006). Peat is the primary form of coal, which develops successively from lignite, charcoal, anthracite, graphite, and finally becomes coal through exposure to heat and pressure from burial beneath other sediments. As it is compressed, it changes chemically into low-grade coals such as lignite, and under further heat and pressure is converted to higher-grade coal. Peat is considered a biomass resource by the Ontario Power Authority (OPA 2005), even though they did not analyze its performance or environmental characteristics because of its relatively negligible role in current biomass energy development.

Peatlands are wetland ecosystems where peat production rates exceed decomposition rates. They are often described as wetland areas with decaying or fossilized plant matter in water saturated areas where lack of oxygen limits decomposition. Wetlands are described by the National Wetlands Working Group (1988) as "land that is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation and various kinds of biological activity which are adapted to a wet environment". MNR's wetland ecosystem classification for northwestern Ontario (Harris et al. 1996) identifies 3 types favourable to the growth of peat based on water and nutrient availability. These include fens, bogs, and marshes and swamps.

Fens are minerotrophic peatlands characterized by a water table at or near the surface and very slow internal drainage. They are often associated with groundwater discharge areas. Peat in fens often exceeds depths of 40 cm and sometimes occurs as a floating mat (Harris *et al.* 1996). Vegetation may include sedges, grasses, reeds, brown mosses, *Sphagnum*, shrubs, and trees. Two subformations of fen, *open* and *treed*, are referred to in this report. An open fen has typical fen characteristics with less than 10% canopy cover by trees, primarily tamarack, that are at least 135 cm high, while a treed fen has similar characteristics but with more than 10% canopy cover by trees (Monenco Ontario 1981).

Bogs, like fens, are identified by a water table at or near the surface. However, a bog's surface is often raised above the surrounding terrain. Because of this isolation from the surrounding terrain, bogs are often very acidic, nutrient poor, and support limited vegetation diversity. Peat usually exceeds depths of 40 cm (Harris et al. 1996). Bogs are considered ombrotrophic peatlands that depend on precipitation for water and nutrient supply. Two subformations of bog, *open* and *treed*, are referred to in this report. An open bog has typical bog characteristics with less than 10% canopy cover by trees, primarily black spruce, that are at least 135 cm high, while a treed bog has similar characteristics but more than 10% canopy cover by trees (Monenco Ontario 1981).

Marshes are grassy wet areas, periodically inundated up to a depth of 2 m with standing or slowly moving water while **swamps** are defined as wooded wetlands where standing to gently flowing waters occur seasonally or persist for long periods on the surface (Monenco Ontario 1981). Marshes and swamps are usually eutrophic with no or very shallow peat.

Peat within swamps and marshes is not often harvested due to the presence of trees, roots, and vegetation. Fens and bogs are the primary peatland types considered for peat extraction.

Peatland habitats are characterized by the relative position of the water table. The first group comprises habitats that form in depressions where the water table is close to the surface. Referred to as lawns or hollows depending on the area they cover, these habitats are dominated by *Sphagnum* species from the group *Cuspidata*, which tend to grow in loose colonies and are not adapted to retain water. Sedges and other graminoid species also occur in these habitats (Quinty and Rochefort 2003).

The second group comprises habitats that form when the water table is below the surface, forming plateaus or hummocks. These habitats are normally about 40 to 80 cm higher than lawns or hollows and thus are drier. The dominant species of *Sphagnum* that colonize these habitats is known as *Acutifolia*, which tends to form dense colonies that retain water. The drier conditions also permit various shrubs and trees to grow, including leather leaf and black spruce, as well as other mosses and lichens (Quinty and Rochefort 2003).

Peatlands support complex ecological functions such as the regulation of global climate and catchment hydrology.

• Regulation of global climate

The natural effect of peatlands on climate occurs through the greenhouse gases [carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)] they both absorb and emit and the carbon they store. A detailed examination of peatland carbon cycling and emissions is pertinent to understanding their complex role in the regulation of climate.

Northern peatlands store about one-third of the terrestrial soil carbon (C) pool (455 Pg C; 1 Pg = 10^{15} g = 1 Gt = 10^3 Mt), which represents 60% of current atmospheric C (Aselmann and Crutzen 1989, Gorham 1991). Of this, they sequester approximately 76 Mt C annually for long-term storage as peat (Gorham 1991). Thus, northern peatlands are important to the global C cycle.

Canada has the second largest area of peatlands (1.24 x 10^6 km^2) in the Northern Hemisphere (Tarnocai 1984). These peatlands contain 154 x 10^3 Mt C accounting for approximately one-third of the C in northern peatlands (Tarnocai 1998). Ontario contains approximately 30% of the peatland area in Canada, thus Ontario peatlands likely play an important role in Canadian and global peatland C budgets (McLaughlin 2004).

Total peatland C storage in Ontario is estimated as 47.1 x 10^3 Mt C, representing 30% of C stored in Canadian peatlands and about 10% of C stored in northern peatlands worldwide (McLaughlin 2004). Peatlands in Ontario dominated by black spruce contain the most C, followed by bogs (open, shrub, treed), thicket swamps, and fens (Figure 2).

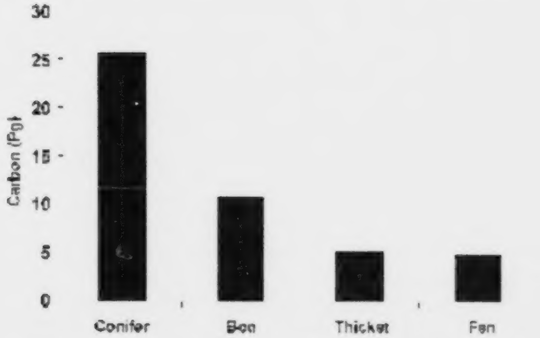

Figure 2. Carbon storage in different peatland types in Ontario (from McLaughlin 2004).

Total methane (CH_4) emissions from Ontario peatlands are 0.48 Mt yr^{-1} (McLaughlin 2004), or 10.08 Mt CO_2 equivalents, using a 100-year Global Warming Potential (GWP) and 3.12 Mt CO_2-C equivalents, using a 500-year GWP (IPCC 2001a). This accounts for about 10% of the approximately 105 Mt CO_2-C yr^{-1} flux (100-year GWP) from Canadian peatlands (Moore and Roulet 1995) and 1% of the 630 to 1050 Mt CH_4 yr^{-1} (100-year GWP) from northern peatlands worldwide (Fung et al. 1991, Bartlett and Harriss 1993). However, it is well documented that 10 to 70% of annual CH_4 emissions are emitted from northern peatlands during the winter months and during spring snowmelt (Alm *et al.* 1999; Lafleur *et al.* 2001, 2003; Elberling and Brandt 2003). Therefore, the estimates of CH_4 emissions should be viewed as conservative.

Ontario's peatlands have one of the lowest CH_4 emission rates (McLaughlin 2004). This is because the organic matter is of low quality for the microorganisms that are involved in CH_4 production (Yavitt et al. 2000, 2005; Kuder and Kruge 2001). In addition, most peatland types in Ontario are conifer, open, and shrub bogs (Riley and Michaud 1989, Riley 1994, McLaughlin 2004), which emit less CH_4 than more productive sedge-dominated fens (Strom et al. 2003).

Net ecosystem exchange (NEE) of CO_2 is commonly used to determine the short-term C source/sink function of peatlands (Lafleur et al. 2001, 2003; Aurela et al. 2002). Ontario peatlands are estimated to take up 8.62 Mt CO_2-C yr^{-1} or 29 g CO_2-C m^{-2} yr^{-1} on an aerial basis for the short-term based on NEE of CO_2 (McLaughlin and Jurgensen *in review*). These values compare to 10.64 Mt CO_2-C yr^{-1} or an aerial uptake of 36 g CO_2-C m^{-2} yr^{-1} for long-term CO_2 sequestration in Ontario peatlands (McLaughlin 2004). Both estimates are within the range of data reported for Canadian and northern peatlands worldwide (Gorham et al. 2003, Lavoie et al. 2005). The calculations based on NEE of CO_2, however, require further refinement because relatively few studies on NEE in Ontario peatlands exist. In addition, as with CH_4, winter emissions of CO_2 can account for 15 to 50% of the annual NEE of CO_2 in northern peatlands (Aurela et al. 2002, Lafleur et al. 2003). Furthermore, inventory data for area harvested, burned, or the successional stages of peatlands are not available, complicating calculations of C balances and predictions of effects of disturbance and climate change on peatland C balances in Ontario.

Based on a carbon balance calculated by McLaughlin and Jurgensen (in review), Ontario peatlands are a net sink of 8.14 to 10.16 Mt C yr^{-1}. However, using a 100-

year GWP, Ontario peatlands range from a net source of 1.46 Mt CO_2-C equivalents yr^{-1} to a net sink of 0.56 Mt CO_2-C equivalents yr^{-1} and using a 500-year GWP are a net sink of 5.50 to 7.52 Mt CO_2-C equivalents yr^{-1}.

• Regulation of catchment hydrology

Peatlands are complex hydrological systems that regulate the hydrology of entire catchments by increasing the surface water retention of a given area and acting as reservoirs. Hydrology affects the physical and chemical characteristics of a wetland which in turn influences flora, fauna, and ecosystem dynamics (Daigle and Gautreau-Daigle 2001). The hydrological regime within peatlands is controlled by two distinct layers, the *catotelm* and the *acrotelm*. The catotelm is the bottom layer of peat that is permanently below the water table. It is composed of relatively decomposed compacted peat and water moves through it very slowly (Quinty and Rochefort 2003). The acrotelm overlies the catotelm, and is the layer in which water table fluctuations occur. Its thickness usually varies between 30 and 50 cm but this largely depends upon the habitat (hummock or hollows) (Quinty and Rochefort 2003). The acrotelm consists of the living parts of mosses and dead and poorly decomposed plant material. It has a very loose structure that can contain and release large quantities of water, minimizing variations in the water table in peat bogs.

Peatlands store water in many ways: in standing water at the peat surface or in pools, through gravitational water held in the acrotelm, or in smaller pore spaces of the catotelm (Daigle and Gautreau-Daigle 2001). Undisturbed peatlands rely on this two-layered structure to regulate the storage and discharge of water.

Sphagnum mosses also play a significant role in the regulation of catchment hydrology. They are primitive mosses comprising a single stem with attached single cell leaves. Their water retention capability is primarily due to their cellular structure and the large number of small pores (Monenco Ontario 1981). This water holding capacity of is not a life function but rather a mechanical capillary function that is retained long after the moss dies (Monenco Ontario 1981). As a result, peat can retain up to15 times its weight in water with *Sphagnum* mosses contributing directly to maintaining water saturation, especially for plateaus or hummock peatlands.

b) Peat Types

The most common peat classification system is von Post's humification scale, which ranges from H1 (undecomposed peat) to H10 (completely decomposed peat with no discernible plant structure) (Monenco Ontario 1981). To be used as a fuel source, peat must be classified as H4 or greater. H4 and H5 peat are described as slightly, to moderately decomposed peat that, when squeezed, releases very muddy dark water, with pasty residues (Monenco Ontario 1981). To qualify as fuel peat, it must also have a high density and low ash content.

While the International Peat Society distinguishes three types of fuel peat (listed below as classified by Andriesse 1988), for northwestern Ontario Peat Resources Ltd. is proposing a form of pelleted peat that does not fit into any of the commercial peat categories because of its much lower moisture content (of approximately 10%).

• Sod peat

Air-dried sod peat is manually or mechanically compressed for fuel. The size and shape of the product, either cylindrical or brick shaped, depends on the production method. Hand-cut sod peat is about 125 x 125 x 300 mm, whereas mechanically produced sod peat is 10 to 30 cm long and 5 to 10 cm in diameter. The moisture content of sod peat is between 30 and 40%.

Compression occurs during production and the sod shrinks and hardens during air drying by the wind and sun. Air-dried sod peat has a higher calorific value per unit volume than milled peat and can therefore be transported more economically. Sod peat is used most widely as a household fuel.

• Milled peat

Milled peat is a heterogeneous mixture of loose peat particles cut from the surface of the peat swamp. The particle size, which varies with the production method, peat type, and degree of decomposition, is between 3 and 8 mm. The moisture content of milled peat ranges between 40 and 50%.

The peat is cut by large-scale mechanized extractions and used either as a power station fuel or as raw material for briquettes. Because of its low bulk density and relatively high moisture content, the calorific value of milled peat per unit volume is low and economics restrict transport distance. Milled peat is the most common fuel peat type used in Finland and Ireland.

• Peat briquettes

Artificially dried and highly compressed peat briquettes or pellets are uniformly sized making them easier to

Table 1. Percentage of area occurring as peatlands and total peatland area for northeastern and northwestern Ontario ([a] *from Riley (1994);* [b] *from Riley and Michaud (1989)).*

Study area	Open bog	Treed bog	Open fen	Treed fen	Conifer swamp	Hardwood/ mixedwood swamp	Thicket swamp	Marsh	Total peatland area	% of total area as peatland
	% total peatland area								ha	
Northeastern Ontario[a]										
Hearst	1.3	8.1	4.4	6.3	58.0	0.2	16.9	4.9	338,889	21.2
Foleyet	1.1	11.7	1.6	5.4	74.7	0.4	3.2	2.0	292,420	17.8
Cochrane-Kapuskasing	8.8	23.2	2.1	1.2	53.2	-	9.2	2.3	528,795	33.1
Timmins-Kirkland Lake	8.2	19.6	0.4	1.5	50.6	-	14.9	2.2	321,290	15.3
New Liskeard	2.2	3.2	2.9	0.6	60.7	0.6	28.3	1.6	107,555	13.0
Total	5.2	15.8	2.3	3.5	58.1	0.2	12.2	2.7	1,588,949	20.5
Northwestern Ontario[b]										
Rainy River	13.0	12.2	7.6	9.1	19.6	5.2	26.7	6.5	116,112	26.2
Dryden-Lac Seul	4.5	25.4	3.4	7.4	41.8	<0.5	11.9	5.2	84,341	3.5
Sioux Lookout	6.6	9.1	9.9	7.5	50.6	-	13.5	2.8	95,096	5.9
Ignace	4.6	19.7	5.0	15.2	43.8	-	6.8	5.1	193,536	12.1
Armstrong	5.2	21.7	5.7	21.4	32.4	-	10.4	3.1	9,580	2.8
Longlac-Nakina	2.0	4.6	5.8	16.4	52.8	1.3	11.6	9.5	201,508	8.4
Total	5.5	13.4	6.2	12.6	42.9	1.3	13.1	5.1	700,173	8.0

Table 2. Average total peat depth (m) estimates for northeastern and northwestern Ontario ([a] *from Riley (1994);* [b] *from Riley and Michaud (1989)).*

Study area	Open bog	Treed bog	Open fen	Treed fen	Conifer swamp	Hardwood/ mixedwood swamp	Thicket swamp	Marsh
Northeastern Ontario[a]								
Hearst	2.2	2.4	2.0	2.3	1.3	-	1.1	1.8
Foleyet	2.9	2.3	2.3	2.2	2.0	-	-	1.6
Cochrane-Kapuskasing	2.3	1.6	3.8	2.3	1.0	-	0.8	-
Timmins-Kirkland Lake	2.4	1.9	2.4	2.1	1.6	-	1.3	-
New Liskeard	4.3	3.4	1.9	1.5	1.9	1.3	1.9	-
Northwestern Ontario[b]								
Rainy River	3.6	4.0	2.6	2.8	3.2	-	2.0	1.3
Dryden-Lac Seul	2.0	1.9	1.9	1.7	2.5	-	0.9	2.5
Sioux Lookout	2.8	2.3	3.1	2.3	2.0	-	0.8	-
Ignace	2.4	2.4	2.2	2.6	1.8	-	2.0	3.4
Armstrong	2.7	2.5	2.0	2.1	-	-	-	-
Longlac-Nakina	2.8	2.9	2.4	2.1	0.8	-	-	-

Table 3. Regional peat volume estimates for northeastern and northwestern Ontario (*[a] from Riley (1994); [b] from Riley and Michaud (1989)*).

Study area	Open bog	Treed bog	Open fen	Treed fen	Conifer swamp	Hardwood/ mixedwood swamp	Thicket swamp	Marsh	Total
					Volume (x 10^6 m^3)				
Northeastern Ontario[a]									
Hearst	99.0	628.6	329.3	446.1	2,554.2	5.6	628.1	167.1	4,858.0
Foleyet	100.2	750.1	96.4	397.7	3,058.2	12.0	110.9	57.0	4,564.5
Cochrane-Kapuskasing	1,021.6	2,084.8	384.4	152.6	2,249.6	-	389.8	123.9	6,406.7
Timmins-Kirkland Lake	607.8	1,260.8	61.4	219.5	2,112.4	-	576.0	69.9	4,907.8
New Liskeard	77.1	96.0	65.8	9.8	1,175.0	8.0	425.7	17.5	1,874.9
Total	1,905.7	4,820.3	937.3	1,225.7	11,149.4	25.6	2,130.5	432.4	22,612
Northwestern Ontario[b]									
Rainy River	498.8	553.0	256.1	317.5	113.9	60.0	434.3	106.4	2,340.0
Dryden-Lac Seul	124.4	557.6	71.7	124.6	528.3	4.0	100.0	43.9	1,554.8
Sioux Lookout	155.6	182.2	282.9	150.1	721.2	-	128.6	26.8	1,647.4
Ignace	238.0	987.6	223.5	615.7	1,268.8	2.0	131.6	97.6	3,564.8
Armstrong	13.0	49.9	12.7	49.2	46.5	-	10.0	3.0	184.3
Longlac-Nakina	1,104.9	270.7	316.4	692.7	1,595.1	25.3	234.6	111.1	4,350.8
Total	2,134.7	2,601.0	1,163.3	1,949.8	4,273.8	91.3	1,039.1	388.8	13,642

handle than either milled peat or sod peat. Milled peat is mechanically compressed to form briquettes, which are similar to bricks in size, whereas pellets are 3 to 30 mm depending on the machine used. Milled peat raw material varies in moisture content from 40 to 55% and must be artificially dried to between 10 and 20% to produce either briquettes or pellets. The calorific value of both briquettes and pellets is high per unit volume and therefore it is economically feasible to transport them over longer distances than either sod or milled peat.

c) Provincial Peat Inventory

Many reports present estimates and inventories of Ontario's peatlands (Monenco Ontario 1981, Riley and Michaud 1987, Riley 1994, McLaughlin 2004) yet uncertainty remains about the availability of fuel-grade peat due to significant variability in estimates and inventory techniques. Generally, the estimates imply much potential for peat for both energy and non-energy uses, but until the variability in estimates is reduced, it is difficult to confirm a realistic inventory of fuel-grade peat in northwestern Ontario, in relation to proposed extraction and consumption estimates.

Ontario contains 312 780 km^2 of wetlands, which represents 30% of Ontario's land area (Figure 3) (McLaughlin 2004). Ninety-three percent of the wetland area in Ontario is classified as peatlands (Tarnocai *et al.* 2000).

National distribution of peat is another indicator of the potential for peat use in Ontario. The total area of peatland for all of Canada is more than 1.1 million km^2 (Belanger and Dubois 1988). Of that, Ontario retains over 20% of peat deposits representing approximately 16 million ha of peatland area (Monenco Ontario 1981). Nearly 10 million ha of the peatland in Ontario are south of the permafrost limit.

The following tables, adapted from Riley and Michaud (1989) and Riley (1994) provide location-specific and peatland type-specific data on area (Table 1), depth (Table 2), and volume (Table 3) for both northwestern and northeastern Ontario. Peat classification types most applicable to current peat extraction interests are highlighted. Study sites for the northwestern Ontario peatland inventory are provided in Appendix 2.

d) Economic Value of Peat Harvesting versus Economic Value of Natural Peatlands

Peat is a major northern natural resource and has been identified as a potential contributor to energy production. Its development has been minimal to date, largely because there were cheaper, more readily available alternatives (Monenco Ontario 1981). The economic viability of peat as a fuel depends on the availability of other fuels, labour,

Peatlands Assessment Case Study: The Dog River-Matawin and English River Forests

Harris and Foster (2004, 2005) examined peatlands in the Dog-River Matawin and the English River forests (Ignace – Upsala areas) to identify those that may be provincially significant or have significant wildlife values. Wetlands were evaluated for provincial significance based on biological features, such as productivity, biodiversity, and size, as well as special features including ecosystem age, relative rarity of wetland type, occurance of rare plants and animals, and habitat potential for colonial waterbirds, ungulates, waterfowl, migratory birds, and fish.

The Dog River – Matawin Forest (see Appendix 3 for study area) supports approximately 220,000 ha of wetlands comprising 23% of the area. This includes about 73,000 ha of bog and fen peatland, covering 7.8% of the area (Appendix 4). Using two models to estimate wetland evaluation scores based on attributes derived for each wetland, Harris and Foster (2005) conclude that a total of 41 wetlands greater than 100 ha were assessed, and 34 are estimated to be provincially significant (Appendix 5).

To the west of the Dog-River Matawin is the English River Forest (see Appendix 6 for study area), where over 50 000 ha are bog and fen peatlands, covering 4.5% of the area. Of the 59 wetlands greater than 100 ha, Harris and Foster (2004) conclude that 34 are provincially significant (Appendix 7). Another 18 wetlands were close to being provincially significant.

material costs, transportation distances, accessibility, climatic conditions, and scale of operation. Unknown, but significant energy costs are assumed to be associated with wet mining extraction, transportation, and production of peat pellets. Costs associated with mitigation and restoration should also be considered in an analysis of economic viability of peat harvesting. Given the uncertainty of effective techniques for wet mining restoration, these costs may be significant.

Limited information is available about the economics of peat harvesting for Canada. Canada's first and only peat-fired generating station, Dapp GS, was taken offline in May 2000 after only two years of service. It was determined that the boiler, developed to burn another fossil fuel, was inadequate to burn fuel peat. Dapp GS was a 17 MW facility that was relocated from California in 1998 to the city of Westlock, Alberta. It was intended be an economic answer for power and would utilize the millions of acres of peat removed for agriculture around the city. At only 17 MW, it required 25 tonnes per hour of fuel (Primarypower 2006). Given that little information is available about the economic viability of the Dapp GS with peat-fired generating stations in Canada, a brief examination of Finland's experience may be useful.

Finland utilizes peat primarily at co-generation power plants (Combined Heat and Power – CHP) fuelled by a combination of peat, wood waste, and process waste. The Kymin Voima Oy plant, for example, was constructed as a multi-fuel power plant close to nearby paper mills. The plant generates 80 MW of electricity, 125 MW of process steam, and 55 MW of district heat. The fuel is 75% wood-based and 25% peat. A number

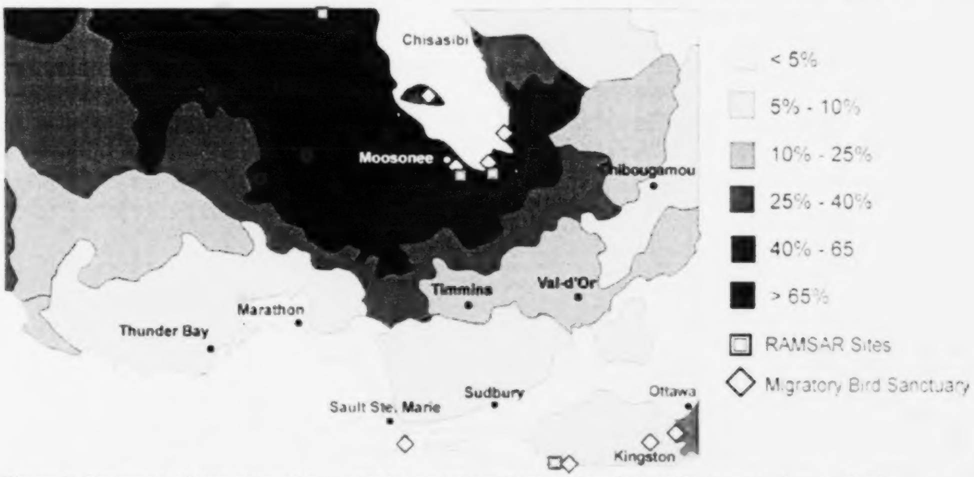

Figure 3. Proportion of area covered by wetlands in northern Ontario (from Natural Resources Canada 2006)

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Figure 3. Proportion of area covered by wetlands in northern Ontario (from Natural Resources Canada 2006).

of examples in Finland demonstrate that conversion of old coal boilers to multi-sourced biomass operations is feasible. The technical functionality, profitability, and fuel administration of these power plants are mostly secured through the joint use of wood and peat (Pohjolan Voima Oy 2005).

The success of peat as a viable fuel source ultimately depends on the relative energy available from other fuel sources. As shown in Table 4, the net calorific value of peat is quite low relative to other similar fuels.

• Economic value of natural peatlands

Natural areas, including wetlands, provide numerous goods and services that have associated economic values and non-use benefits and serve as sources of natural capital (Olewiler 2004, Anielski and Wilson 2006). Examples of ecosystem services that wetlands provide include disturbance regulation, water supply and regulation, food production, greenhouse gas mitigation, nutrient cycling, genetic resources, biodiversity, recreation and cultural pursuits (Olewiler 2004). MNR's strategic direction, *Our Sustainable Future*, presents the concept of sustainable development, linking it directly to natural resources as 'natural capital' and accumulation of natural capital as 'interest', reinforcing the idea that the economic value of ecological goods and services should be included decision-making.

Putting an economic value on ecological services is a challenging prospect but there is growing recognition that such natural benefits have real economic value and that these values need to be included in decision-making processes (Environment Canada 2001). Because these services typically have no market price, a measure of their values may be obtained through non-market valuation techniques (Woodward and Wui 2001). Table 5 provides examples of both use and non-use economic benefits of wetlands, including intangible and hard to quantify benefits to society.

Approaches to valuing natural capital fall into two categories: (i) a focus on economic damages and (ii) the willingness of individuals to pay for goods and services from natural capital or willingness to accept compensation for the loss of natural capital (Woodward and Wui 2001). These methods rely on case studies and present a range of estimates.

Table 4. Net caloric value of peat fuel relative to other fossil fuels.

Fuel	Net Calorific Value
Sod peat	14.0 MJ/kg (3.98 MWh/t)
Peat briquettes	16.2 MJ/kg (4.50 MWh/t)
Peat pellets	16.2 MJ/kg (4.50 MWh/t)
Lignite coal	21.0 MJ/kg (5.83 MWh/t)
Subituminous coal	24.0 MJ/kg (6.67 MWh/t)
Bituminous coal	31.0 MJ/kg (8.61 MWh/t)
Anthracite coal	32.0 MJ/kg (8.89 MWh/t)
Fuel oil	43.0 MJ/kg (11.94 MWh/t)
Natural gas	49.0 MJ/m3 (10.83 MWh/t)

(Adapted from Hasanen et al. 1986, Monenco Maritimes 1986, and Nordisk Innovations Center 2005)

Table 5. Examples of the economic benefits of wetlands (from Environment Canada 2001).

USE BENEFITS		NON-USE BENEFITS	
Direct	**Indirect**	**Option**	**Existence**
Recreation • Boating • Birding • Wildlife viewing • Walking • Fishing Trapping-hunting Commercial harvest • Nuts, berries, grains • Fish • Peat • Forestry • Trapping-hunting	• Retain nutrients • Filter water • Control floods • Protect shorelines • Recharge groundwater • Support external ecosystems • Stabilize micro-climates • Control erosion • Maintain associated expenditures (e.g., travel, guides, gear, etc.)	• Protect potential future uses (as per direct and indirect uses) • Maintain future value of information (e.g., pharmaceuticals, education)	• Conserve biodiversity • Retain culture • Support heritage • Increase bequest value

Olewiler (2004) illustrates the value of natural capital by examining case studies such as the Lower Fraser Valley. Estimates of the savings in waste treatment costs provided by the area's wetlands (i.e., absorption of nitrogen and phosphorus from fertilizer leaching) are a starting point. Olewiler estimates that the annual nitrogen and phosphorus waste treatment benefits received from the existing 400 000 ha of wetlands could amount to between $18 and $50 million per year, and represent a small part of the total value of the wetlands to the region. Other studies have put the annual value of all the goods and services (fish, waterfowl, mammal and reptile habitat, water supply, erosion, flood control, and recreational opportunities) generated by one ha of wetland between $5 792 and $24 330. It is difficult to apply these figures on the total wetland area, however, because not all wetlands provide each of the goods and services indicated.

Destroying natural capital may also be economically inefficient because then substitutes are required for the services this capital provides. Substitutes (in the case of peatland extraction this includes restoration) may be far more expensive than those provided by nature (Olewiler 2004).

Numerous studies stress the importance of incorporating the total economic value of natural peatlands in management planning (Mitsch and Gosselink 2000, Soderqvist et al. 2000, Woodward and Wui 2001). Turner et al. (2000) summarize the complex relationship between the different levels of wetland functions, uses, and values. They explain that wetland management planning requires a framework that combines economic valuation, integrated modelling, stakeholder analysis, and multi-criteria evaluation.

e) Resource Extraction and Harvesting Methods

Common methods of **dry peat mining** include sod cutting, vacuum extraction, and milled peat harvesting primarily for horticultural use but also for fuel peat burning. Dry mining involves draining the peatland first to allow it to dry naturally over a period of time. The loosened surface, which dries rapidly, is scraped off. The peat is cut and collected into heaps before being transported to the user. Moisture content is usually about 50%.

Wet mining, on the other hand, is an application for fuel peat burning and involves removing peat without any on-site solar drying and transporting it to a plant for further dewatering and thermal drying. The advantages of wet mining are that it allows extraction to occur in areas where drainage is impossible, greatly increases the production season, and is relatively cost-effective (Monenco Ontario 1981). The many 'unknowns' associated with wet mining, as well as a dearth of research and literature, make it challenging to provide a thorough explanation of the process. While understanding of the removal and transportation processes is limited, generally, the process follows five steps:

- Removing surface vegetation
- Dredging raw peat from the unprepared peatlands
- Preparing the peat slurry
- Pumping the slurry to a dewatering plant
- Mechanical dewatering to an acceptable moisture level

Peat Resources Ltd., for example, is developing a wet mining process to produce peat fuel. The process starts with wet mining of raw peat. A proprietary upgrading step is followed by mechanical dewatering to 40% solids (by weight) through a continuous high pressure press. The dewatered peat is then dried to the desired moisture content using heat to achieve a density comparable to coal.

Since wet mining is a relatively new extraction method, most literature concentrates on dry peat mining. Accordingly, the following descriptions will focus on dry mining.

i) Dry Mining Pre-harvest Preparations

Beyond infrastructure preparations (i.e., roads, buildings) and approval processes (i.e., environmental assessments, public consultation), a fundamental pre-harvest preparation for dry mining is **draining** the peatland. Drainage plans must consider the size and layout of fields and include the orientation of all ditches, roads, and field storage piles.

An undisturbed peatland averages about 95% moisture content, requiring the formation of ditches to drain off existing ponds to isolate the drainage ditches of the site from surrounding terrain and to accelerate the drainage rate of spring melt waters during the pre-production stage. Multiple cuts of the same ditch are required as ditches tend to close up rapidly (Monenco Ontario 1981).

ii) Dry Mining Harvesting and Processing Methods

Following the draining process, dry peat can be extracted in a number of ways:

• Sod peat production

Sod cutting involves blocks of peat that are cut and extracted to dry. 'Extruded' sod mining is best suited to Ontario conditions. A peat extruder, attached to a standard farm tractor, continuously extrudes peat sods that break into 10 to 15 cm pieces. The sod is left to

air-dry on the field, then is wind-rowed, and collected mechanically for transport (Mankinen andFraser 1981).

• Milled peat production

Milled peat harvesting involves a series of steps: milling, harrowing, ridging, and harvesting, as categorized by Bord na Móna (2001) below.

Milling
Milling refers to the cutting and shredding of the top 12 to 25 mm of surface to be dried. In the milling operation a thin layer of peat, usually about 15 mm deep, is cut from the surface of the bog where it is left to air dry over a period of a few days. Typically, the water content of the thin layer of peat is 80% after milling. The miller itself consists of a number of rotating drums fitted with pins to cut the peat. It is towed and powered by an agricultural tractor.

Harrowing
During drying, the layer of peat is turned a few times. This is achieved with a machine called a harrow, which consists of a series of turning elements called spoons that are towed behind a tractor. The spoons turn down the dry surface of the peat layer and expose the wet peat underneath to the sun and air to expedite drying.

Ridging
When the layer of peat on the surface of the bog has reached the target water content it is collected into ridges in the middle of each field. This is done with a ridger, a machine consisting of a series of blades in the shape of a V that spans the full width of the field. The blades are towed by a tractor and push the peat to the centre of the field.

Harvesting
Andriesse (1988) outlines the most common methods used for harvesting milled peat:

1. In the *Peco method*, the peat is first collected into ridges along the length of the fields at 10 to 20 m intervals. The ridge on the fifth field from the stockpile is picked up by a harvesting machine, passed along a conveyor and dropped on top of the ridge on the fourth field from the stockpile. This process is repeated in "leap frog" fashion until all the peat is harvested onto the stockpile.

2. In the *Haku method*, each ridge is picked up by the same type of harvester, loaded onto a trailer, and taken to the central stockpile. The operations of milling, harrowing, ridging, and harvesting are repeated for each crop.

3. The *Harvester method* uses self-loading trailers or harvesters to collect the peat and carry it to stockpiles at the end of the fields. Stockpiles are smaller – 6 to 8 m high – and because the material is loosely piled, there is some danger of internal combustion.

• Vacuum peat production

Harvesting can also be carried out pneumatically. A thin layer from the dry upper part of milled peat can be extracted at daily rates of 5 to 15 tonnes per ha.

iii) Dry Mining Post-Processing

• Dewatering

The dewatering of peat is an energy-intensive process of removing undesired water by mechanical or chemical means. The mechanical method uses pressure to break down the fibres of the peat and squeeze out the water. This can reduce the water to between 65 and 70%. Thermal drying of the peat can further reduce moisture to less than 15%. The chemical process of dewatering involves breaking down the chemical structure of the peat by as much as 10%, thereby permitting the mechanical dewatering process to remove upwards of 35 to 50%.

Extracted peat from a wetland can contain up to 90% water, thus cannot be used as a fuel until dewatered. In general, fuel peat should contain less than 50% water or be manufactured into briquettes or pellets with less than 15% moisture content (Monenco Maritimes 1986).

• Conversion into fuel

Peat can be converted into either a gaseous, liquid, or solid form for combustion in a process similar to that of converting coal.

The creation of **gaseous fuels**, through gasification, typically involves the reaction of peat with steam and air or oxygen at high pressures and temperatures to convert the carbon in peat to various combustible gases (e.g., carbon monoxide, hydrogen, methane). Other by-products of this type of conversion include tars and oils that can be used as fuel for the gasification process (Monenco Maritimes 1986).

Liquid fuels can be produced through hydrogenation of peat, which also removes oxygen, nitrogen, sulphur, and ash. One of the several methods of hydrogenation is pyrolysis, which involves the thermal degradation of peat into char, combustible gases, tars, oils, and other liquid hydrocarbons. Other liquid fuels can also be produced by direct and indirect hydrogenation of peat. Direct hydrogenation is a process whereby elevated temperatures and pressures produce liquid fuels. Indirect hydrogenation produces liquid fuels by the dissolution of the peat in solvents that act as hydrogen donors (Monenco Maritimes 1986).

The most common peat-derived fuels utilized in the production of energy are **solid fuels** produced by the pressing or the partial cooking of dried peat, containing less than 15% water, into briquettes and pellets. Solid fuels are common due to the relative simplicity and economic viability of conversion. The conversion of peat into solid fuels makes transportation and storage far more economical (Monenco Maritimes 1986).

- **Storage**

Proper storage is important to ensure the dried peat does not regain lost moisture (through precipitation) and to prevent environmental and health issues arising from any dust. It is common to leave peat in mounds and use a sprinkler system to moisten the upper layer when necessary to prevent dust or to store the raw peat in an enclosed or covered structure. Peat that has been processed into briquettes or pellets is stored in large covered storage buildings either at the site of processing and/or at the generating station.

- **Transportation**

The transportation of peat from the extraction site to the generating station can be the most cost prohibitive aspect of peat-fired power production, due to peat's relatively low bulk density. Studies have shown that the cost of fuel peat approximately doubles for every 150 km of transport (road or rail) and the most economic fuel peat utilization scenarios are adjacent to peatlands (Monenco Ontario 1981).

Narrow gauge rail is used in Finland to transport peat to generating stations. In Ireland, Bord na Móna utilizes locomotives and cars that are produced in-house to the specifications required. The rail systems are intended to be removed and relocated once the peat resource has been exhausted.

Large quantities of easily accessible, fuel-grade peat in northwestern Ontario are located near railroad networks, the Trans-Canada Highway system, and Thunder Bay's port facilities on Lake Superior, making transport more feasible in terms of cost than other potential locations.

The economic viability of transporting peat to be used as a fuel largely depends on the form of peat being transported. For example, onsite processing of peat into briquettes or pellets makes transportation far more efficient than transporting unprocessed, air-dried peat or wet peat slurry.

iv) Restoration

The last stage of the extraction process is planning and implementing restoration techniques. Section 4 examines collected knowlede gained from Canadian experiences in restoration of peatlands mined for horticultural purposes.

f) Peat as Fuel: A Jurisdictional Scan

Given that Canada has limited experience mining fuel peat, it is useful to look at development and extraction experiences from other jurisdictions. Within Europe, particularly in Finland and Ireland, peat is an important local or regional energy source. It also continues to be important in the Baltic States, Sweden and Russia (Table 6).

- **Finland**

Table 6. Production of peat for energy from other northern countries during the 1990s (in million tonnes per year) *(data from Joosten and Clarke 2002).*

Country	1990	1997	1998	1999
Belarus	3.4	2.7	2.0	3.1
Russia	6.0	2.9	1.9	3.7
Ukraine	1.3	0.6	0.6	0.5
Estonia	0.0	0.2	0.2	0.6
Finland	5.8	10.1	1.5	7.5
Ireland	7.5	4.0	4.3	4.7
Sweden	0.0	1.4	0.2	1.1
Peat Resources Inc. proposed production:				0.2

Conversion of Facilities for Peat Burning: Atikokan and Thunder Bay

Ontario Power Generation has not evaluated conversion requirements for Atikokan and Thunder Bay coal burning plants. Given the age of the plants, Azimuth Environmental Consulting (2005) expects that the technology conversion costs would be significant.

Modifications are likely to include changes to the fuel handling system since peat burns faster than coal. Additional technology options also need to be investigated and include the addition of limestone or co-generation with biomass fuels (e.g., wood, wood chips, or wood wastes) as a way to minimize emissions from peat burning (Azimuth Environmental Consulting 2005).

Peatlands constitute about a third of the surface of Finland (Vasander et al. 2003). With rising import fuel prices, peat in Finland has recently gained an increasingly stronger position, a 6% share of primary energy input, constituting 16% of the fuels fired in large, 200-plus MW combustion plants used in 1998. In energy terms, the largest consumption of Finnish peat is in large combustion power generating stations and heating plants of the inland city systems serving populations of 50,000 to 200,000 people.

Peat is also used in co-generation (CHP). The total installed capacity is over 750 MW of electrical capacity and 1500 MW of thermal capacity, and includes 60 district heating plants, 34 CHP facilities, 30 industrial plants, and one condensing power plant (Joosten and Clarke 2002). Finnish peat companies have 120 000 ha of peatlands at their disposal, which is enough to guarantee constant peat supplies until the middle of this century (Vasander et al. 2003).

- **Ireland**

Ireland maintains a long history of peat use for fuel. While originally extracted by hand cutting, today modern industrially milled peat accounts for 13% of the country's power needs, generating power in six peat-burning condensing power plants, as well as providing a fuel source for household space heating. The older generation of pulverised fuel is being phased out and will be replaced by fluidized-bed plants with a combined capacity of 370 MW (Joosten and Clarke 2002).

The Irish company Bord na Móna supplies about 3 million tonnes of milled fuel peat per annum to power stations for electricity generation. These receiving power plants are located close to concentrations of peat producing areas and are connected to these areas by a narrow-gauge industrial railway network. Bord na Móna transports most of its fuel-grade peat by rail, typically for 8 to15 km. The remainder is trucked in by road from non-connected outlying peat producing areas within 45 to 80 km. The delivered price of peat is €8 to 10 ($11 to 14 CAN) per MW hour (Fitzgerald, Bord na Móna, pers. comm., 2006).

- **Canada**

Within Canada, Quebec and New Brunswick maintain extensive peat mining operations, almost exclusively for horticultural purposes (Robert et al. 1999, Daigle and Gautreau-Daigle 2001, Girard et al. 2002).

Peat as an Energy Source: An Introduction to Sustainability Considerations

A recent study by Schilstra (2001) discusses the sustainability of peat as an 'alternative' fuel, addressing current debates about emissions, re-growth of peat, and peatlands as carbon sinks. In relation to concerns about emissions during burning, regrowth rates, and effects on carbon stores, Schilstra emphasizes over-arching conditions for the sustainable use of natural resources as:

- Renewable resources should not exploited at a rate higher than their regeneration level
- Non-renewable resources should not be depleted at rates higher than development rate of renewable substitutes
- Absorption and regeneration capacity of the natural environment should not be exceeded.

Using Finland as a case study, Schilstra argues that peat extraction is not sustainable relative to these conditions. Likewise, Price et al. (2003) reiterate Schilstra's concerns that peat extraction should not be considered sustainable based on the profound alterations to the hydrological and ecological functions at a local and regional scale.

Industrial producers frequently claim that peat is a sustainable resource (i.e., Canadian Sphagnum Peat Moss Association) based on global figures that estimate that the annual volume of peat extraction is a small fraction of net global peat accumulation.

Diverging perspectives on the long-term sustainability of fuel peat extraction challenge decision-making processes for peat extraction development. A thorough and well-informed consideration of the environmental impacts of extraction, as well as the potential for successful restoration, are thus central for future policy and decision-making.

3. Cumulative Impacts of Fuel Peat Mining

a) Socio-economic Opportunities

Literature focusing on the economic spin-offs associated with large-scale peat for fuel operations are limited. Cruikshank and Tomlinson (1995) briefly discuss peat development in Northern Ireland as a function of economic development and a solution for rural areas experiencing high unemployment.

Despite the lack of literature in this area, it can be generally concluded that the socio-economic benefits of converting coal generating stations into peat-fired plants would include continued employment for single-industry towns, as well as local opportunities for extraction and restoration activities.

b) Environmental Impacts of Peat Harvesting

Peatland ecosystems exist as the result of multiple sensitive interactions between hydrology and vegetation, and are thus affected by changes in climatic conditions and disturbances such as drainage, peat harvesting and forest harvesting, all of which significantly affect wetland functions, aquatic resources, ecosystem productivity, and the ability of peatlands to act as effective carbon sinks (McLaughlin 2004). Generally, environmental impacts of peat harvesting can be categorized as terrestrial, aquatic, hydrological, and emissions-related.

i) Terrestrial

Wetlands contribute significantly to regional diversity by harbouring endemic and uncommon species of plants, insects, birds and small mammals (Mazerolle 2003). The most significant environmental impact of large-scale peat extraction from a terrestrial perspective is the overall reduction in northern boreal wetland area and its acute effect on biodiversity. The following is a summary of potential impacts of peat harvesting on terrestrial systems (Daigle and Gautreau-Daigle 2001, Mazerolle et al. 2001, Price et al. 2003, Azimuth Environmental Consulting 2005):

- Loss of unique fen communities and bog/fen combinations with special microhabitat features such as patterning, water tracks
- Loss of wetland connectivity leading to genetic bottlenecks and loss of wildlife migration corridors
- Reversion of wetland fragments to drier habitats
- Loss of habitat for unique species of wildlife utilizing wetlands (i.e., whooping crane, wood bison, trumpeter swans, moose, caribou, and beaver)
- Increase in the potential for flash fire episodes
- Proliferation of non-native plant species, impacting plant successional patterns and nutrient cycling
- Reductions in size of peatland complexes
- Loss of vegetation species richness, including rare and endangered flora

ii) Aquatic and Hydrological

Peat harvesting changes the hydrologic, hydrogeological, and water quality of watersheds. Generally speaking, peat mining removes or impairs delicate hydrological conditions that maintain the existing peatland and adjacent wetland community types. Due to the natural variability of wetlands and their supporting ecosystems, the impact of discharging peatland water will vary; however, several common direct and indirect impacts to aquatic and hydrological regimes include (Monenco Ontario 1981, Heathwaite 1994, Prevost and Plamondon 1999, Daigle and Gautreau-Daigle 2001, Price *et al.* 2003, Azimuth Environmental Consulting 2005):

- Impact on spawning habitat in or near wetlands compromised by increased levels of suspended sediments and other contaminants
- Significant increases in stream flow temperature fluctuations
- Elevated levels of ammonia, organisms, and total nitrogen, phosphorus, aluminium, and iron
- Changes to evapotranspiration affecting ground heat flux (caused by large differences in soil thermal diffusivity (a function of moisture content) and ground temperature (peatlands freezing deeply because of little vegetation to trap snow) caused by draining and extraction
- Changes in turbidity and chemistry of discharge from peatlands into watercourses, and adjacent wetlands through increased overland runoff or ground water inputs
- Increase of heavy metals (i.e., mercury) and acidity in adjacent waterbodies
- Eutrophication of neighbouring ecosystems from sudden release of stored phosphorus from peat into surface waters
- Sedimentation and contamination of watercourses as a result of runoff from extraction sites and potential loading of area watercourses/waterbodies with impurities and trace metals previously bound within the peat deposits

- Increases in runoff, peak flows, and base flows as a result of drainage
- Flooding as a result of higher base flow contribution to area watercourses following harvesting
- Potential loss of reservoir function and water storage capacity of peatlands as a result of removing acrotelm layer and exposing the catotelm

iii) Effect on Greenhouse Gas Emissions and Climate Change

Peatlands affect, and are affected by, climate. Ontario's boreal peatlands are an important part of the Earth's carbon cycle, and serve to remove and sequester large amounts of carbon from the atmosphere for extended periods. Peat mining results in the emission of greenhouse gases into the atmosphere, including carbon dioxide and methane.

Although peat has been mined by humans for centuries, most work to explore the relationship between peat extraction and climate change has been completed since the mid-1990s by scientists in a number of countries, including Sundh et al. (2000), Tuittila *et al.* (2000, 2004), Uppenberg et al. (2001), Waddington et al. (2002), Gornam and Rochefort (2003), Petrone et al. (2003), Glatzel et al. (2004), Nilsson and Nilsson (2004), Zetterberg et al. (2004), and Cleary et al. (2005). In Canada, most research has focused on the impact of peat extraction for horticultural purposes.

• Life-cycle analysis

Determining the effects of peat mining on the ecosphere by measuring the emissions and calculating the global warming potential of trace gases (also referred to as radiative forcing) is generally completed in a four-stage process (Uppenberg et al. 2001) that includes use of a control sample. Therefore, measurements are made (1) in a non-manipulated peatland, (2) a drained peatland before extraction (0 to 5 years), (3) during peat extraction, transport, and combustion, (6 to 25 years), and (4) after-treatment [e.g., peatland restoration (>25 years)]. The net greenhouse gas emissions are then calculated as the difference between emissions from a mined peatland and a non-manipulated peatland.

In model calculations, the area affected by the drainage, is assumed to be twice the size of the extraction area (Uppenberg et al. 2001). This assumption is based on the influence of distance of the drainage ditches, which are 20 to 30 m outside the extraction area. The drainage area that is not used for extraction (i.e., *the surrounding area*) is used for storage piles and access roads. Based on these assumptions, every 1 m^2 of peatland used for peat extraction will cause 1 m^2 of *surrounding area* to be drained.

There is general agreement that during peatland drainage operations, CO_2 effluxes increase significantly above pre-disturbance values (from -100 to 100 g CO_2 m^{-2} yr^{-1} to 1,500 g CO_2 m^{-2} yr^{-1}) in both the extraction and surrounding areas (e.g., Uppenberg et al. 2001, Waddington et al. 2002, Petrone et al. 2003, Nilsson and Nilsson 2004). During the extraction of peat (years 6 to 10), an additional 1,500 g CO_2 m^{-2} yr^{-1} net CO_2 is emitted to the atmosphere. From years 11 to 25, emissions decrease to an average of 300 g CO_2 m^{-2} yr^{-1}. Most models predict that it takes 100 to 1,000 years after harvest for a peatland to revert back to a net C sink. Even though these numbers can vary considerably, the time involved causes some researchers to consider peat a non-renewable resource.

The spatial and temporal impacts of a harvesting operation depends on the type of peat harvested. For example, assuming a future climate that is conducive to the reformation of peatlands, highly fertile (nutrient rich) fens can metabolize back to a net C sink within 100 years. However, nutrient-poor peatlands can require 1,000 years or more to convert sufficient organic matter to create a functioning carbon sink (Cleary *et al.* 2005).

Climate

Climate is primarily fuelled by energy (heat) from the sun and created by dynamic and complex interactions between the atmosphere, the hydrosphere, the cryosphere, land, and organisms. Human-induced climate change is a secondary (cumulative) impact resulting from the extraction and burning of fossil fuels, the emission of manufactured chemicals, the drainage of wetlands, and the conversion of forests and grasslands to other uses such as urban development (Gray 2005). Current climate change results from an increase in the amount of energy trapped in the atmosphere by increased concentrations of carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4), and other greenhouse gases. For example, atmospheric CO2 has increased 31% since pre-industrial times (IPCC 2001a).

The method of restoration is an important determinant in the carbon sink/source periods. Techniques that promote peatland hydrology for optimal vegetation growth are most beneficial for decreasing the amount of time a peatland functions as a source (Rochefort 2000, Gorham and Rochefort 2003, Waddington et al. 2003, Tuittila et al. 2004, Zetterberg et al. 2004). For example, blocking drainage ditches after peat extraction increases water table depth, which reduces decomposition and CO_2 production. Higher water tables also stimulate regeneration and growth of *Sphagnum*, which increases CO_2 uptake through photosynthesis (Waddington et al. 2003).

Peat extraction alters the decomposition (microbial breakdown of peat) of a peatland's carbon pool, thereby creating a net source of greenhouse gases. Cleary et al. (2005) modelled the life cycle of peat for Canadian peatlands. They compared CO_2 losses for the following stages: (1) peat decomposition by microorganisms due to lowering the water table; (2) peat extraction, including the use of fossil fuels during the extraction process; (3) transport to market (size, origin, and market destinations of peat shipments) used for each mode of transport (train, truck, ship); and (4) land use change: (i) undisturbed peatland, (ii) peatland under extraction, (iii) abandoned cutover peatland with no restoration, and (iv) cutover peatland under restoration.

Based on this modelling exercise, greenhouse gas emissions in Canada increased from 1990 to 2000 due to peat extraction (Figure 4). During the life cycle of peat extraction, peat decomposition due to lowered water tables contributed the most to CO_2 losses, followed by land-use change, transport to market, and peat extraction and processing (Figure 5). Data from Cleary et al. (2005) are based on peat extraction for horticultural purposes and that fuel-grade peat mining would likely increase greenhouse gas emissions significantly (Nilsson and Nilsson 2004).

In peat harvesting operations, the vegetative production component of a peatland is eliminated and peat decomposition is increased. By the time harvested (cutover) peatlands are abandoned, all vegetation has been stripped away and the hydrological conditions are unsuitable for *Sphagnum* recolonization. In conjunction with the removal of carbon-fixing vegetation, this condition causes an increase in the oxidation of peat and in the continued emission of CO_2, which can be 100 to 400% greater than the CO_2 emissions from an un-harvested peatland (Waddington et al. 2002).

Only 5% of peatlands in Canada (or a specific region) need to be drained/harvested to exceed the annual peatland C sink of the entire country or a region. Consequently, the net sink function would be lost and the peatland resource converted to a net source of atmospheric CO_2. Some regions of Canada, such as eastern Quebec and New Brunswick, where drainage for horticulture is prevalent, may already exceed the 5% threshold (Waddington et al. 2002). Peatland drainage for fuel combustion and horticulture has increased sevenfold since 1940 (Armentano and Menges 1986). Therefore, peat extraction will play a greater role in changes to the global C budget unless efforts are made to restore harvested peatlands or shift their use to forestry (Laiho and Laine 1997, Gorham and Rochefort 2003, Nilsson and Nilsson 2004, Tuttila et al. 2004), but the effects on global C budgets are not well understood.

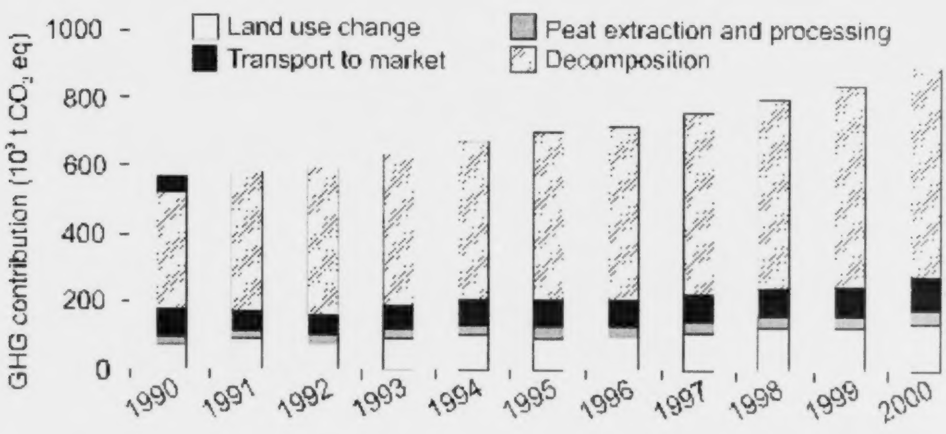

Figure 4. Greenhouse gas (GHG) contribution for the life cycle of peat extraction (from Cleary et al. 2005).

Zetterberg et al. (2004) used three different scenario modelling schemes to evaluate the climate impact from peat utilization in Sweden: (1) peatland-afforestation-bioenergy, (2) peatland-wetland restoration, and (3) multiple generations where 15 generations of peat extraction, with a time delay of 20 years between generations on the same peatland, was used. All scenarios were run for 300 years. Zetterberg et al. (2004) reported modelled values as accumulated radiative forcing (Joules (J)/m² peat/m² extraction area). They also compared the radiative forcing from peat burning to that generated with coal, natural gas, and forest residues assuming 1 MJ (mega joule) of energy was produced per year from each energy source.

The results of Zetterberg et al.'s (2004) study showed that depending on the assumptions in the models, accumulated radiative forcing from peat utilization was less than that generated from coal, and depending on the restoration practice (afforestation vs. herbaceous or *Sphagnum* moss), the accumulated radiative forcing was similar to that from natural gas (Table 7). Forest residues consistently produced the lowest radiative forcing of the energy sources modelled. The peatland restoration scenario that assumed minimum CO_2 uptake, however, was comparable to radiative forcing from coal. This indicates the importance of choice of restoration practice on the radiative forcing of peat harvesting for bio-energy.

• Peat extraction and the Kyoto Protocol

A primary objective of the Kyoto Protocol is to stabilize greenhouse gas (GHG) concentrations in the atmosphere at minus 5 to 6% of 1990 CO_2 concentrations. To meet this objective, reductions in fossil fuel emissions and changes to land-use practices that can be used to increase sinks and/or minimize the net losses of carbon are required (Roulet 2000). Currently, the Protocol

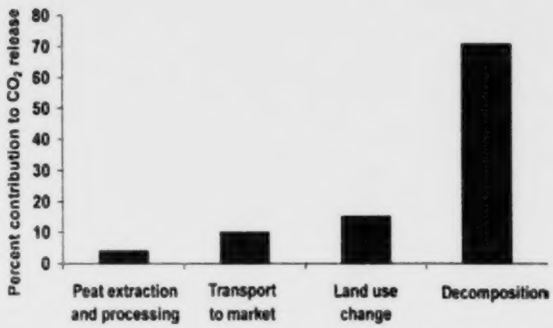

Figure 5. Life cycle of peat extraction in Canada *(from Cleary et al. 2005).*

accepts terrestrial sinks for GHGs as offsets for fossil fuel emissions; however, current discussions suggest that provisions should be made for the inclusion of other land uses and soils, including the sequestration of carbon in wetlands.

Peatlands are a relatively small sink for CO_2 and a large source of CH_4. Although variations among peatlands are large, when the global warming potential of CH_4 is factored in many peatlands can be considered neither sinks nor sources of GHGs (Roulet 2000). Large-scale peat extraction will likely render peatlands a net source.

If peat is mined and used for energy in Canada, the resulting emissions should be documented in the energy sector emissions reporting program. If peat is mined for horticultural purposes, resulting emissions should be documented through the agricultural sector emissions reporting program (Intergovernmental Panel on Climate Change (IPCC) National Greenhouse Gas Inventory Programme Guidelines 2006).

Table 7. Emissions of various fuel sources in relation to that of coal for 300 year period (from Zetterberg et al. 2004).

	CO_2-equivalents (GWP 500) summarized over 300 years		Accumulative radiative forcing at 300 years	
Fuel Source	**kg**	**Relative to coal**	**mJ m⁻²**	**Relative to coal**
Coal	31	1.00	0.160	1.00
Peat-wetland CO2 uptake = min	31	1.00	0.140	0.90
Peat-wetland CO2 uptake = max	14	0.46	0.098	0.63
Peat-afforestation	23	0.73	0.090	0.57
Natural gas	18	0.59	0.083	0.54
Forest residue	2	0.07	0.015	0.09

• Other emissions

Current global attention is firmly fixed on the impact of CO_2 on global climate change; however, other emissions should also be addressed including sulphur and nitrogen oxides, methane, particulates, trace metals, and organic compounds. Table 8 provides a summary of flue gas emissions for peat, coal, and natural gas (Barber 2003, Nilsson and Nilsson 2004). No specific value was found for amount of trace metals and organic compounds in flue gasses.

Methane

Table 8 illustrates the relative difference in methane emissions between peat, coal, and natural gas. The methane emitted from peat burning is significantly less than that from coal but still significantly higher than natural gas. Schilstra (2001) indicates that "as the CH_4 emissions are highly variable between and within fields, generalizations on the total cumulative long-term effects are premature". The radiative effect of methane is about 30 times greater than that of CO_2.

Sulphur dioxide and nitrous oxide

One of the beneficial attributes of peat is its relatively low sulphur content relative to coal. It is this factor that limits the potential emission of sulphur dioxide to a level far below that of coal. For example, Table 8 illustrates the level of sulphur dioxide in peat of 115 g SO_2 MJ^{-1} relative to the higher levels emitted from coal at 550 g SO_2 MJ^{-1}. The combustion of peat in most circumstances occurs at temperatures less than 900°C. At these temperatures, the rate of oxidation of nitrogen is low, which results in negligible generation of nitrogen oxides relative to coal. Nilsson and Nilsson (2004) determined that the burning of peat for fuel produces about half the N_2O that is produced from coal. However it is still nearly 10 times greater than the N_2O emitted by natural gas. In addition, the radiative effect of N_2O is 200 times greater than CO_2.

Particulates and trace elements

Fly ash and dust are common by-products of burning any bio-fuel. For example, a 100M W generation station will produce between 11,000 and 100,000 tonnes of ash per year. These particulates can be effectively removed from the combustion process by using devices such as electrostatic precipitators, baghouses, and cyclones (Monenco Maritimes 1986). Major constituents include oxides of silicon, aluminium, calcium, and iron, with lesser amounts of magnesium, sodium, and potassium (Monenco Maritimes 1986). Like coal, peat can contain at many trace elements, including antimony, arsenic, barium, beryllium, cadmium, cobalt, copper, chromium, lead, nickel, manganese, molybdenum, selenium, strontium, vanadium, zinc, thorium, and uranium (Monenco Maritimes 1986). During combustion, most of these elements are retained with the ash. This ash is commonly disposed of in landfills, which can potentially create significant environmental concerns. Contact of this ashes with water can produce an acidic to highly alkaline solution depending on its makeup.

c) Other Challenges

Little is published about the impacts of peat mining on tourism, recreation, Aboriginal issues and archaeology. Large-scale peat mining may affect diverse groups including sport fisherman and hunters, as well as Aboriginal people who utilize peatlands for picking fruit, harvesting wild rice, fishing, hunting, and other cultural activities. Mitigation strategies may help to minimize impacts on identified groups. Azimuth Environmental Consulting (2005) identified a number of recreation, Aboriginal, and archaeological mitigation strategies:

- Assess the recreational value for sport fishing and hunting of excavation sites to ensure that losses in tourism will not impact the local economy
- Consult with Aboriginal peoples to determine possible locations of archaeological relics, burial grounds
- Systematically sample peat cores within the extraction envelope prior to commencing mining activities to ensure that fossil pollen is preserved for future study and analysis

Table 8. Flue gas emissions of peat, relative to coal, and natural gas *(from Nilsson and Nilsson 2004).*

Flue gas	Peat-fuelled plant	Coal-fuelled plant	Natural gas-fuelled plant
CO_2 (g/MJ-1)	105.2	94.2	59.0
CH_4 (g/MJ-1)	0.005	1.1	2.8 x 103
SO_2 (g/MJ-1)	115	550	-
N_2O (g/MJ-1)	0.006	0.012	0.00056

4. Peatland Restoration and Mitigation

Section 3 identified several environmental impacts of peat extraction that clearly demonstrate the need to consider mitigation techniques and plan restoration efforts. The following discussions primarily introduce mitigation and restoration approaches for horticultural dry harvesting where drainage is involved. To what extent these techniques could be applied to large-scale wet mining extraction, such as the project proposed by Peat Resources Ltd., is not clear. Current restoration knowledge for wet-mining extraction of peat for fuel is superficial and more extensive research is required to inform the discussion of fuel peat restoration.

Furthermore, because most studies are recent, longer-term effects are unknown. Gorham and Rochefort (2003) conclude that wetland restoration after peat harvesting has been studied for too short a period to ensure progression to a fully functional peatland that is compatible with similar nearby unharvested peatland. Long-term monitoring of peatland restoration projects is essential for a better understanding of how to successfully carry out such restoration.

a) Restoration

Before assessing the restoration options available for dry mined peatlands, it is useful to identify the goals of peatland restoration. While no standard management practices can be listed because each site presents unique challenges, the central goal of restoration management remains the same: to re-establish self-regulatory mechanisms that will re-establish functional peat accumulating ecosystems. To expedite this goal, restoration must address peatland revegetation and stabilization of hydrological functions by:

1. Reestablishing a plant cover dominated by peatland species and
2. Rewetting harvested sites by raising and stabilizing the water table near the surface.

Price et al. (2003) point out that it is still uncertain whether the hydrological, ecological, and carbon storage functions of peatlands can be restored. They argue that restoration implies the development, through management, of functions that are *very similar* to those of undisturbed peatlands, but that restoration should not be seen as an attempt to restore peatland *sensu stricto*, except over the long term. Instead, restoration should be viewed in terms of short-term 'rehabilitation'.

Extensive literature exists that examines restoration and sustainable management of horticultural peat mining sites (see for example Robert *et al.* 1999, Daigle and Gautreau-Daigle 2001, Girard et al. 2002, Farrell and Doyle 2003, Quinty and Rochefort 2003), while comparatively limited literature exists on fuel peat extraction restoration (Price et al. 2003,Vasander et al. 2003, Whinam et al. 2003). Although broad similarities exist in the approach to restoration for industrial fuel peat extraction and horticultural extraction, the contexts and physical impacts of these applications differ greatly. Nonetheless, lessons can be learned from horticultural restoration methods.

Numerous studies demonstrate that some mined peatlands have been "spontaneously" revegetated with typical peatland vegetation without reintroduction of plant diasporas (Robert et al. 1999, Girard et al. 2002). Surveys of post-harvested peatland in Québec and New Brunswick, however, suggest that these sites do not rapidly return to their original state if nothing is done at cessation of peat extraction. In fact, only 17% of trenches of former block-cut peat bogs have been recolonized by *Sphagnum* mosses, while *Sphagnum* is almost absent in abandoned milled fields (Quinty and Rochefort 2003). Spontaneous regeneration of *Sphagnum* has only occurred on old block-cut sites where the surface layer of living moss was thrown into the centre of the trenches (M. Browning, OMNR, pers. comm, 2006). Modern extraction techniques do not save the living moss layer.

Girard et al. (2002) discuss the slow recovery of vacuum-mined peatlands compared to block-cut sites, arguing that improved drainage techniques increase soil oxidation and compression, resulting in irreversible changes, and the impact of heavy vacuum machinery is extensive. In addition, they conclude that it is much more difficult to rewet a vacuum-mined peatland even after blocking drainage ditches.

- **Restoration options**

In the *Peatland Restoration Guide*, Quinty and Rochefort (2003) identify the central techniques for restoring peatlands affected by horticultural extraction. Generally, these techniques include:

- Reprofiling or flattening fields to prevent water runoff and distribute water evenly
- Blocking ditches and drainage to keep water within restoration site and improve water distribution
- Creating pools to support a variety of organisms, contributing to biological richness of peatlands
- Building bunds and terracing to limit water movement

- Colonizing vegetation to accelerate the formation of new plant coverage
- Shading and fertilizing to facilitate plant establishment
- Spreading straw to improve growing conditions for plant fragments

Peat extraction affects water output and storage. Thus, storing more water (limiting loss) is an important objective of peatland restoration. Studies show that blocking drainage ditches can be very effective in limiting loss of water by runoff (Quinty and Rochefort 2003). Techniques, like blocking drainage ditches, that promote peatland hydrology for optimal vegetative growth also are most beneficial for decreasing the time for a peatland to revert back to a net CO_2 sink (Rochefort 2000, Gorham and Rochefort 2003, Waddington et al. 2003, Tuittila et al. 2004, Zetterberg et al. 2004). Blocking drainage ditches after peat extraction increases water table depth, which reduces decomposition and CO_2 production. Higher water tables also stimulate regeneration and growth of *Sphagnum*, which increases CO_2 uptake through photosynthesis (Waddington et al. 2003).

The loss of the acrotelm following drainage and the decomposition of peat resulting from its exposure to air greatly reduces the water storing capacity of peat deposits in harvested peatlands. Covering harvested peatlands with a layer of straw mulch is an effective way of reducing evaporative water loss. Building berms is another method of keeping as much water as possible in restoration sites. Following rewetting activities, peat deposits often swell, suggesting that part of water storage capacity can be recovered in the short term.

Quinty and Rochefort (2003) also outline other options beyond revegetation and restoration. One alternative is to focus principally on flooding and water management rather than revegetation. By stabilizing the water table to not less than 40 cm from the surface, suitable conditions for spontaneous colonization of peatland species may be established. This approach has received growing attention in Germany and the Netherlands, yet there is little demonstrated success in North America because of large summer water deficits. The few examples of flooding efforts in Quebec illustrate that little to no spontaneous colonization by peatland species has occurred. Other alternatives include development of agricultural crop and pasture land, and commercial forestry, both which have been applied in Ireland and Finland with success (Vasander et al. 2003).

b) Mitigation

Azimuth Environmental Consulting (2005) identified a number of possible mitigation techniques for reducing the environmental impacts of any large-scale fuel peat extraction:

- Further assess peatlands to identify those with a high natural heritage value, i.e. large size, presence of special features, close proximity to or inclusion of waterbodies and watercourses, areas of sensitive hydrology, potential presence of rare species, presence of high microhabitat richness, areas of fen, and rich fen, areas with a high plant and animal species richness, areas of provincial significance or interest
- Avoid and protect abovementioned areas with a high percentage of features and functions considered significant from a natural heritage planning perspective
- Plan to ensure that landscape connectivity exists between retained peatland fragments post extraction
- Undertake thorough species inventories during the exploration phase of the project to ensure that habitat for rare wetland species is not lost. Do inventory in 3 seasons to ensure that the full range of reproductive and flowering stages of wetland plants are included
- Engineer an appropriate site design (size, location, design of containment ponds and drainage ditches) such that sediment, particulates, and runoff are contained on site and treated to ensure that ground water resources are protected from contamination
- Design the extraction site to take into account the size and nature of buffer vegetation used to fulfill the functions of water purification and filtration that are lost as a result of peat extraction
- Plan extraction rates based on ensuring that *at least* 1 m of peat remains above the underlying mineral layer

5. Summary

Peatlands in Ontario provide a sizeable resource that *could* be utilized for fuel if a proper balance is struck between sustainability concerns and energy targets. Preliminary information gathering clearly demonstrates that wherever feasible, peat extraction should occur in areas with the least potential for environmental impact, which may considerably reduce the area available for extraction.

The general consensus is that fuel-grade peat extraction:

- affects regional biodiversity through wetland loss
- disturbs unique hydrological functions
- affects local water quality
- alters the natural carbon balance of a peatland ecosystem
- increases net greenhouse gas emissions over pre-disturbance values

These conclusions may reduce the potential for using peat extraction for bio-energy generation, however, a number of critical knowledge gaps remain. Firstly, a more comprehensive investigation into the economics of fuel peat harvesting is required. It is challenging to discuss the economic viability of large-scale peat extraction for energy production when, for instance, the costs of conversion are unknown and an economic cost-benefit analysis of estimated value of undisturbed peatlands has not been done. An incomplete picture of the socio-economic opportunities associated with peat extraction makes it difficult to evaluate the balance between environmental impacts and socio-economic opportunities.

Secondly, a more complete understanding of wet mining processes is necessary. Without concrete results from research that exclusively examines large-scale wet mining extraction of fuel-grade peat, many unknowns exist. An attempt to address these key knowledge gaps may facilitate future assessment of sustainable energy alternatives for Atikokan and elsewhere in Ontario.

Finally, uncertainties around associated carbon fluxes and global warming potential are substantial. Inventory data are limited for successional stages of conifer peatlands, area harvested for forestry, and area of different peatland types burned, all of which are critical for carbon balance and global warming potential modelling. A more informed and integrated inventory of different peatland types, disturbance types and frequencies, successional stages after disturbance, peat carbon levels, and gas exchange are necessary to refine current models of peatland carbon balance and to improve our understanding of the potential contribution of peat extraction to greenhouse gas emissions and global warming potential.

This literature review confirms the diverse values and functions associated with peatlands, highlights key environmental considerations associated with potential extraction of fuel grade peat, and presents common restoration and mitigation approaches to peat extraction. It aims to stimulate future discussions about the extraction and allocation of peat as a resource, associated land use policy, implications to climate change, ecological impacts to wetlands, and potential alternatives.

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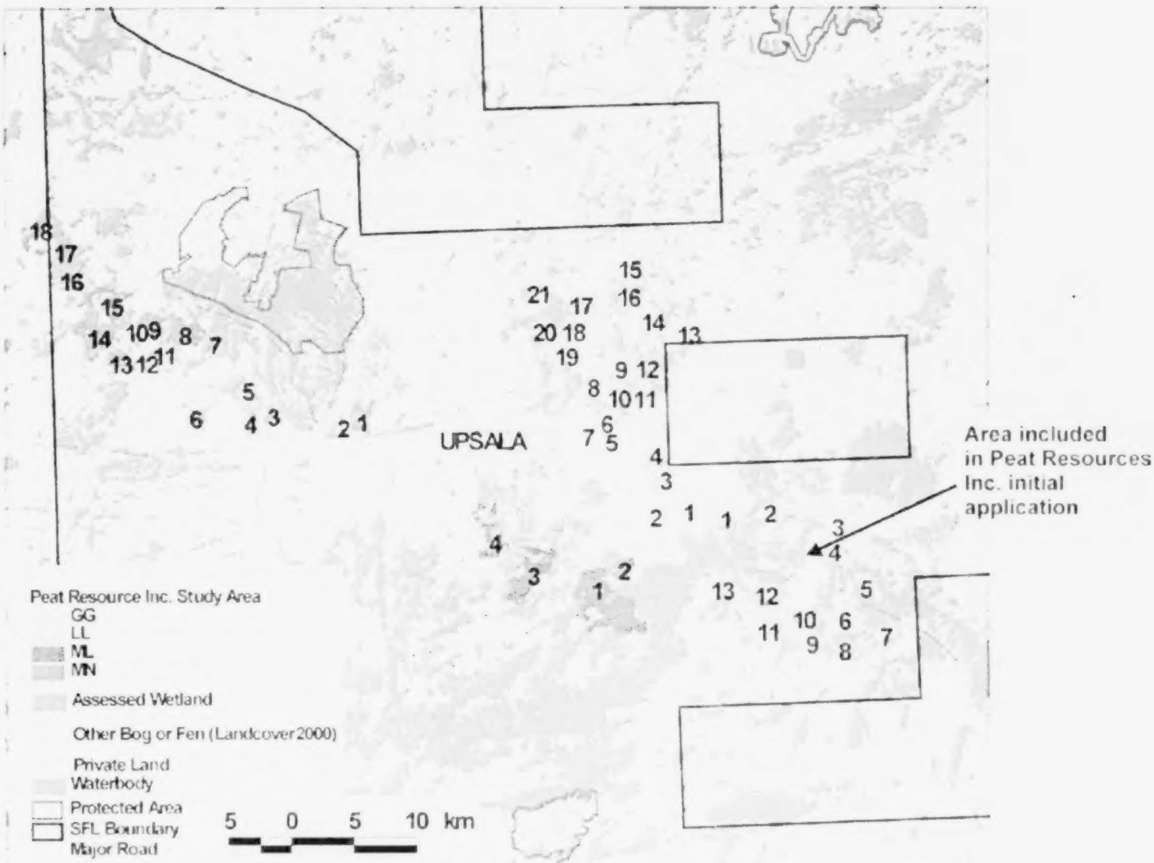
Appendix 1:

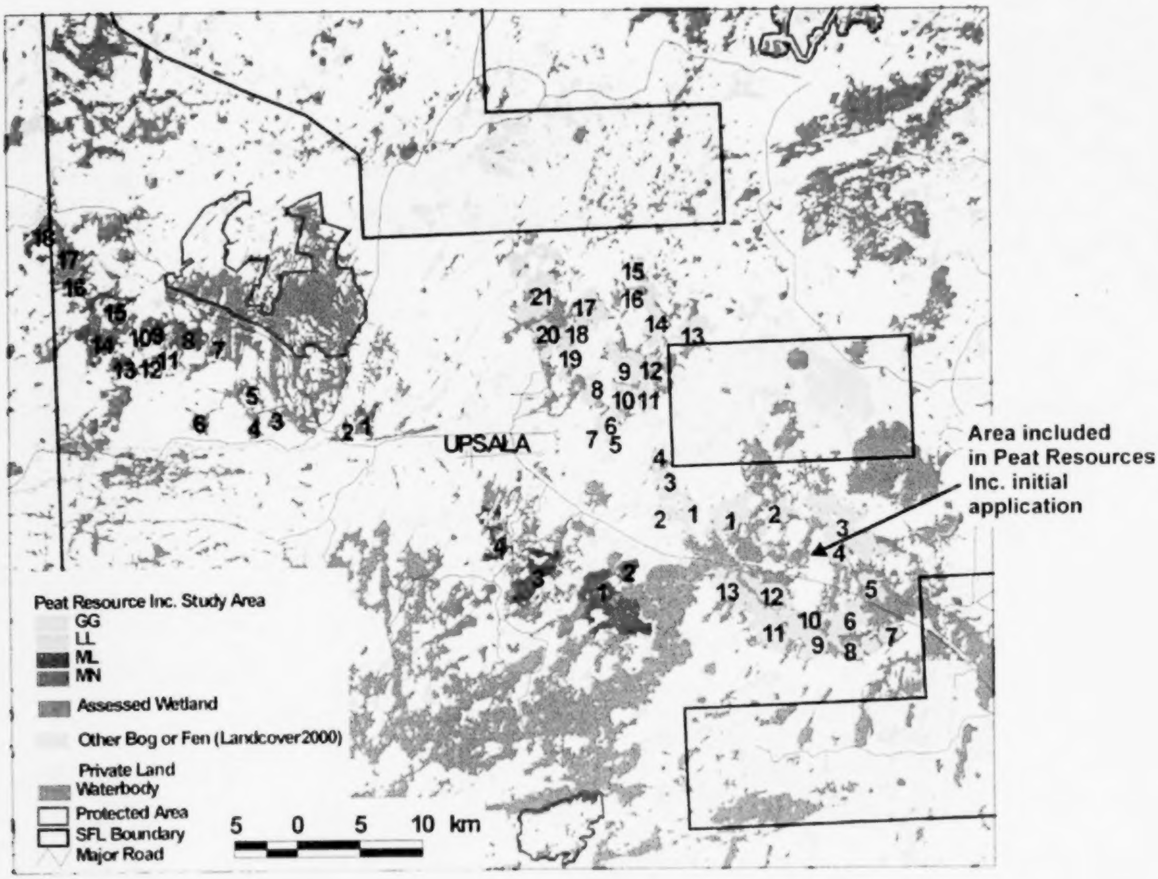
Wetlands surveyed by Peat Resources Ltd. on the Dog River – Matawin Forest, west of Thunder Bay, ON



* The abbreviations (GG, LL, ML, MN) are codes that Peat Resources Ltd. used to identify their study areas. Some correspond to township names (i.e., Goodfellow). The numbers on the map refer to the individual peatlands within their study areas.

Appendix 1:

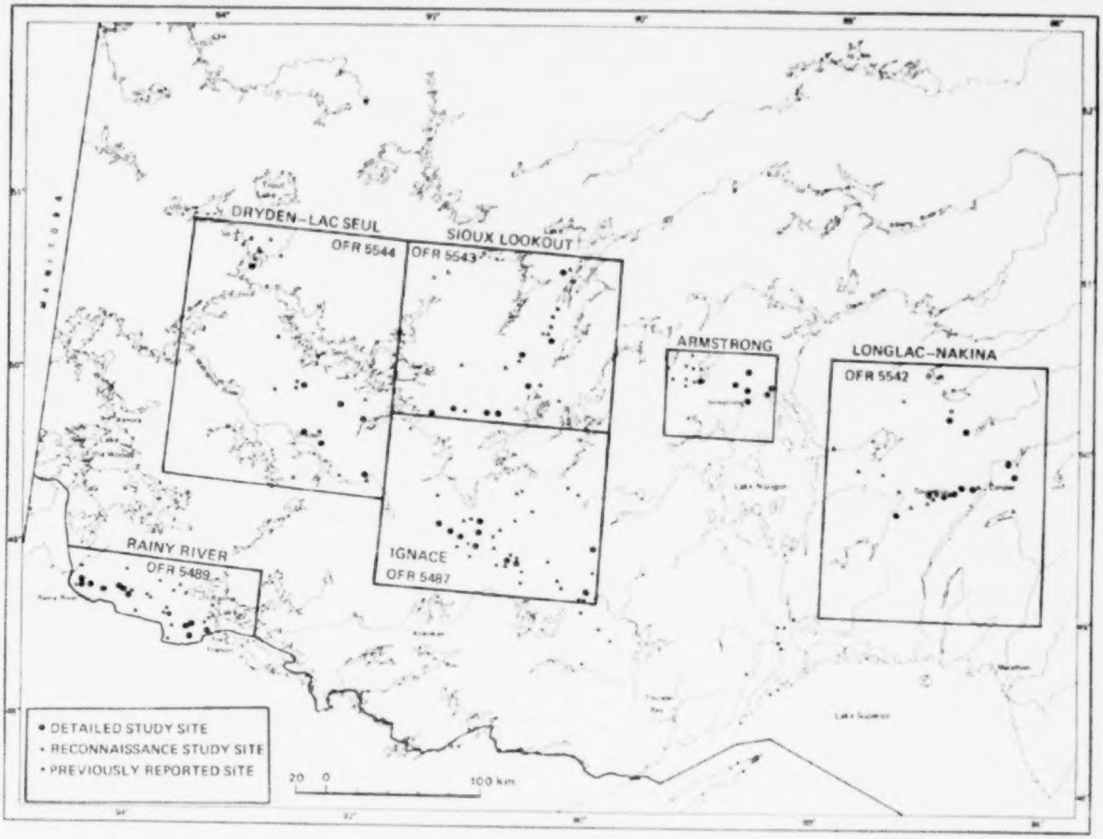
Wetlands surveyed by Peat Resources Ltd. on the Dog River – Matawin Forest, west of Thunder Bay, ON



* The abbreviations (GG, LL, ML, MN) are codes that Peat Resources Ltd. used to identify their study areas. Some correspond to township names (i.e., Goodfellow). The numbers on the map refer to the individual peatlands within their study areas.

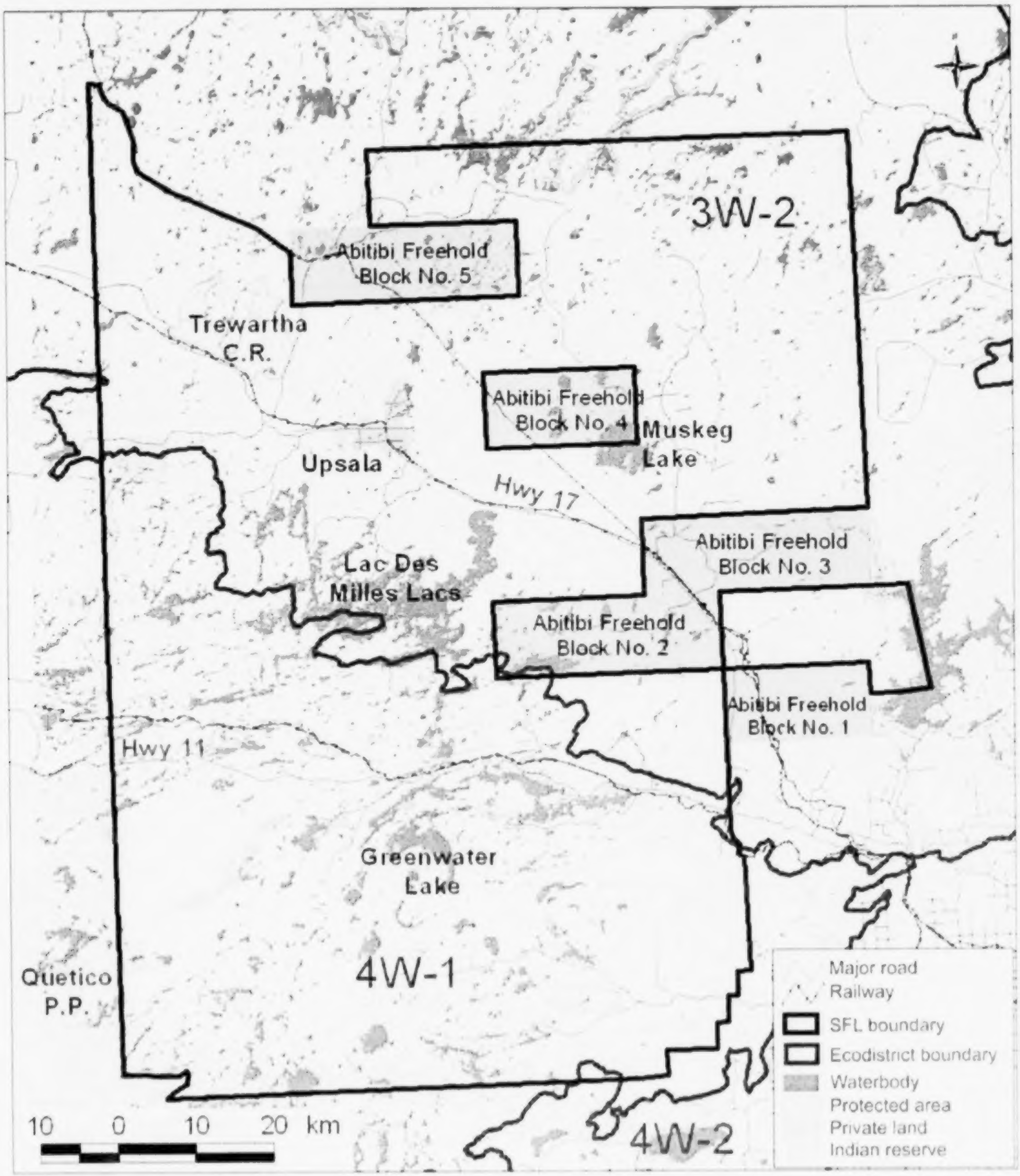
Appendix 2:

Peatland inventory study sites in northwestern Ontario (Riley and Michaud 1989)



Appendix 3:

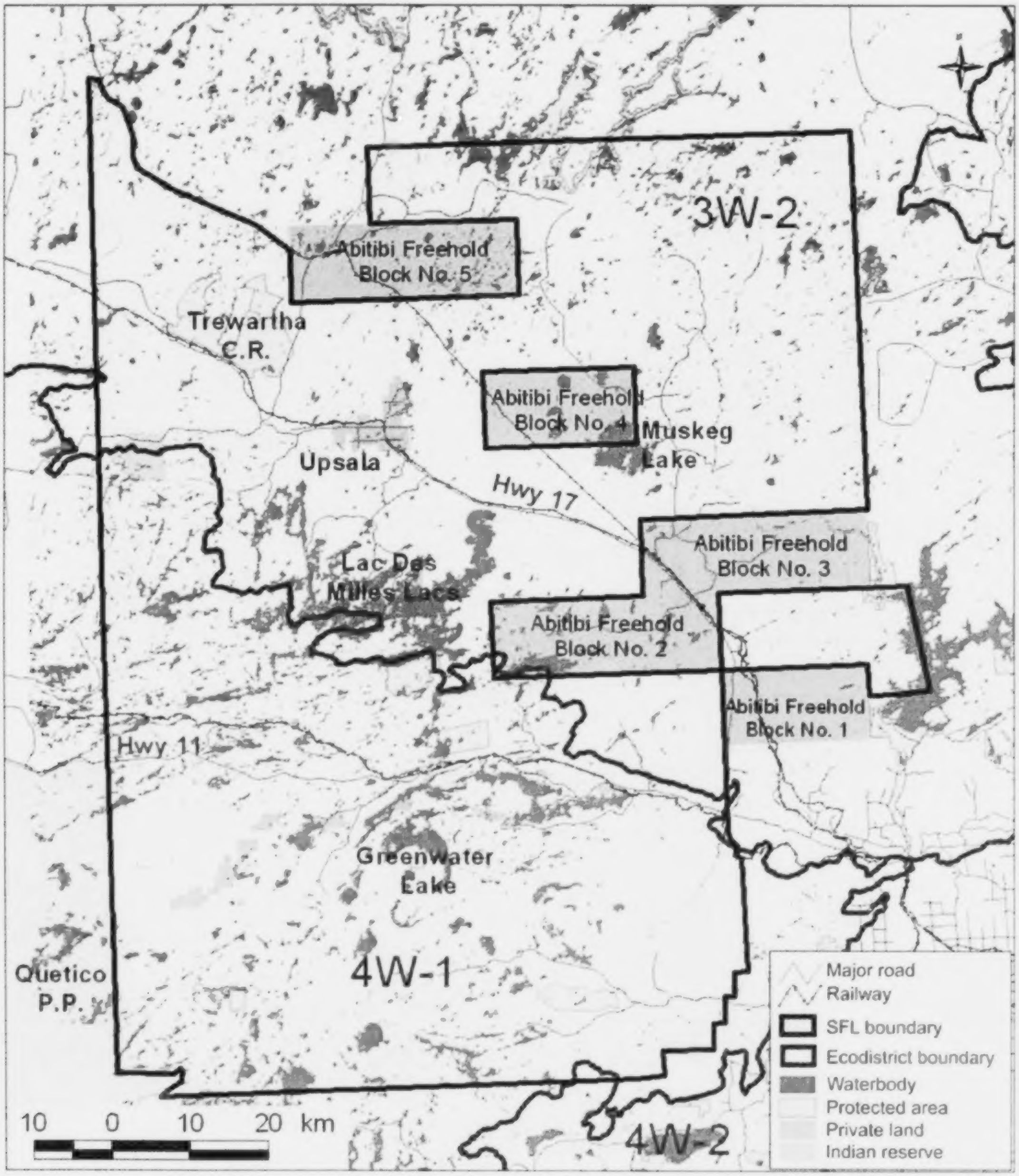
General location of the Dog River - Matawin Forest Management Unit in northwestern Ontario (Harris and Foster 2005)



*SFL Boundary - Sustainable Forest License Boundary

Appendix 3:

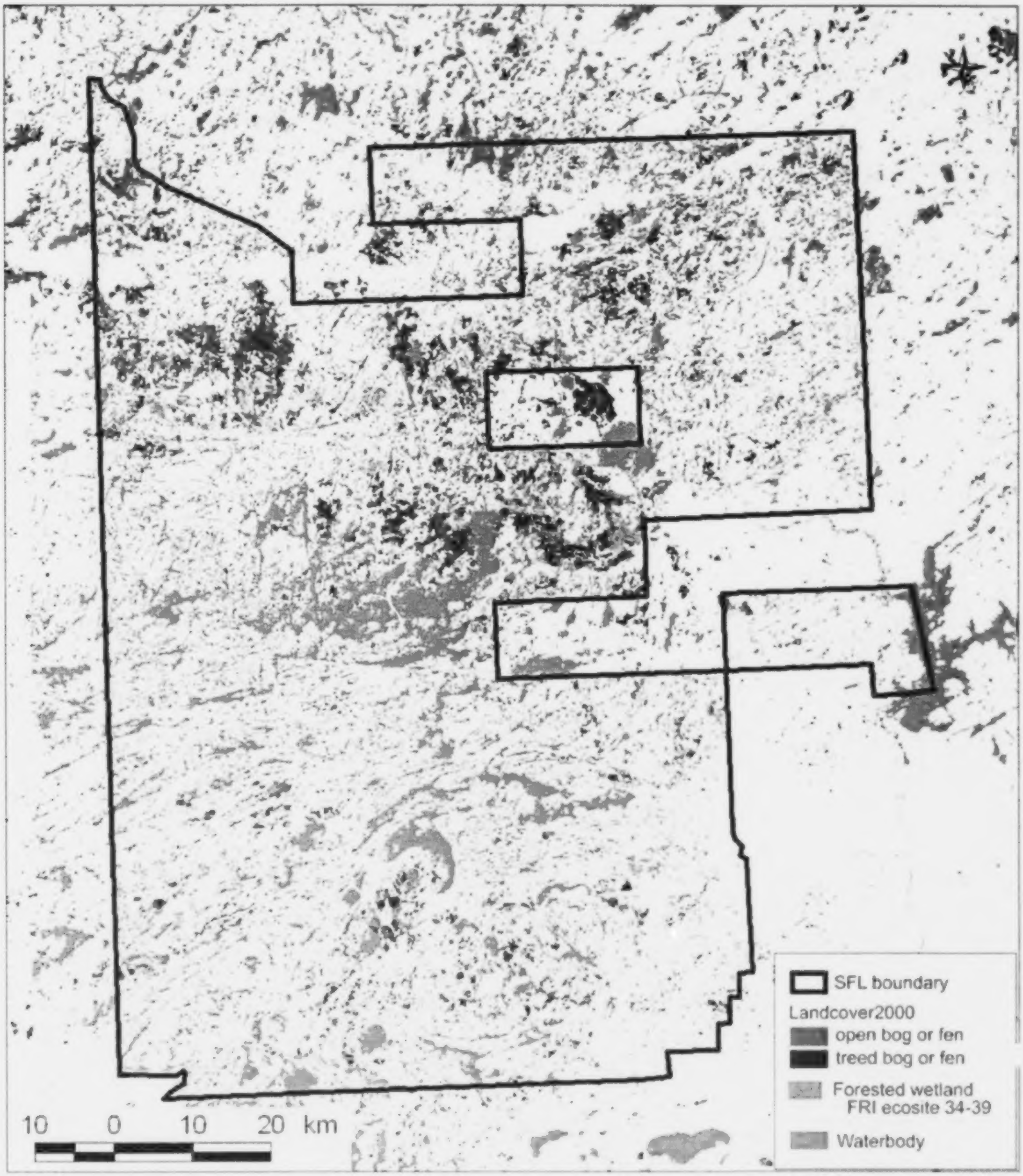
General location of the Dog River - Matawin Forest Management Unit in northwestern Ontario (Harris and Foster 2005)



*SFL Boundary - Sustainable Forest License Boundary

Appendix 4:

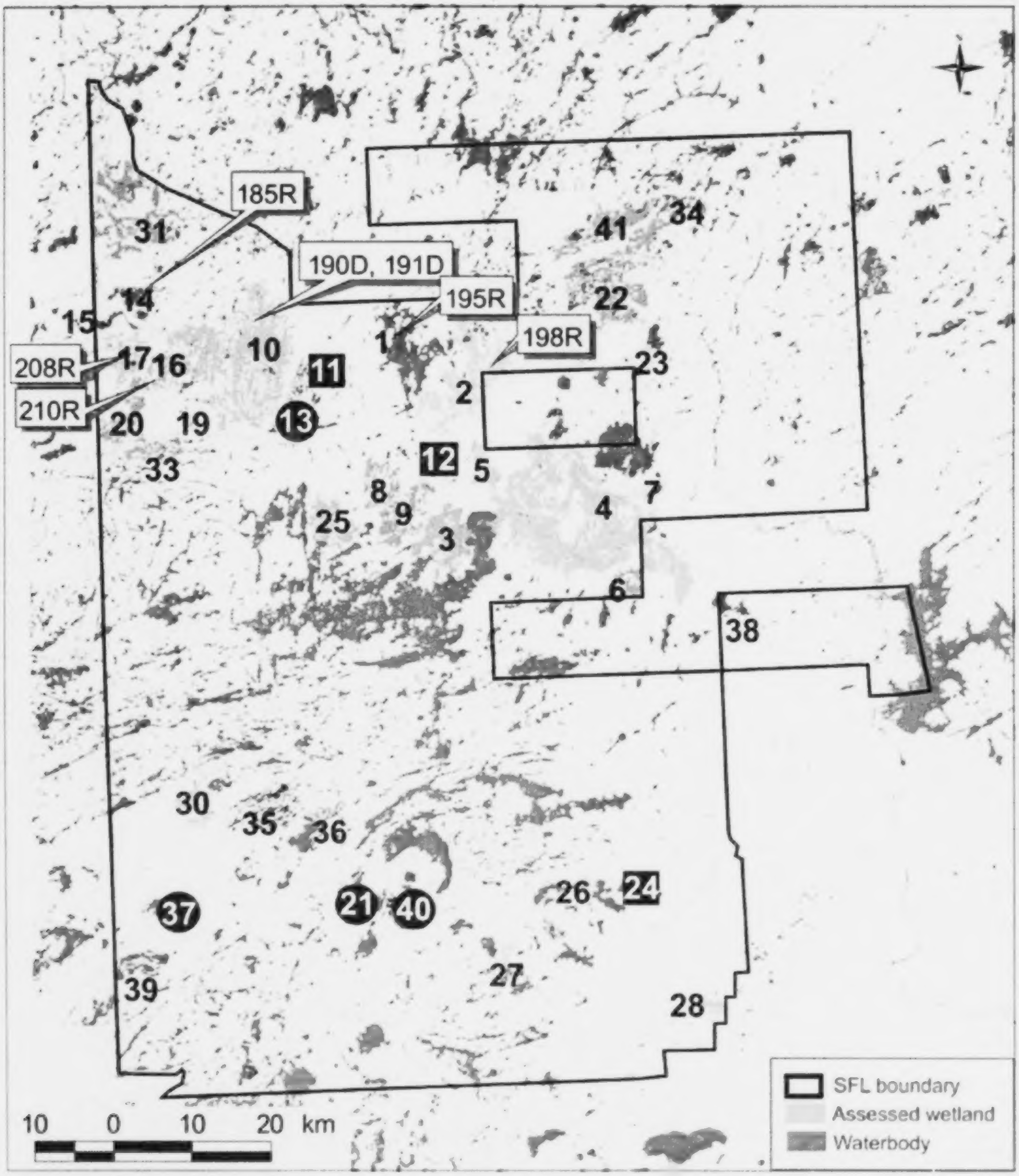
Peatland and forested wetland (swamp) distribution on the Dog River – Matawin Forest (Harris and Foster 2005)



*SFL Boundary - Sustainable Forest License Boundary

Appendix 5:

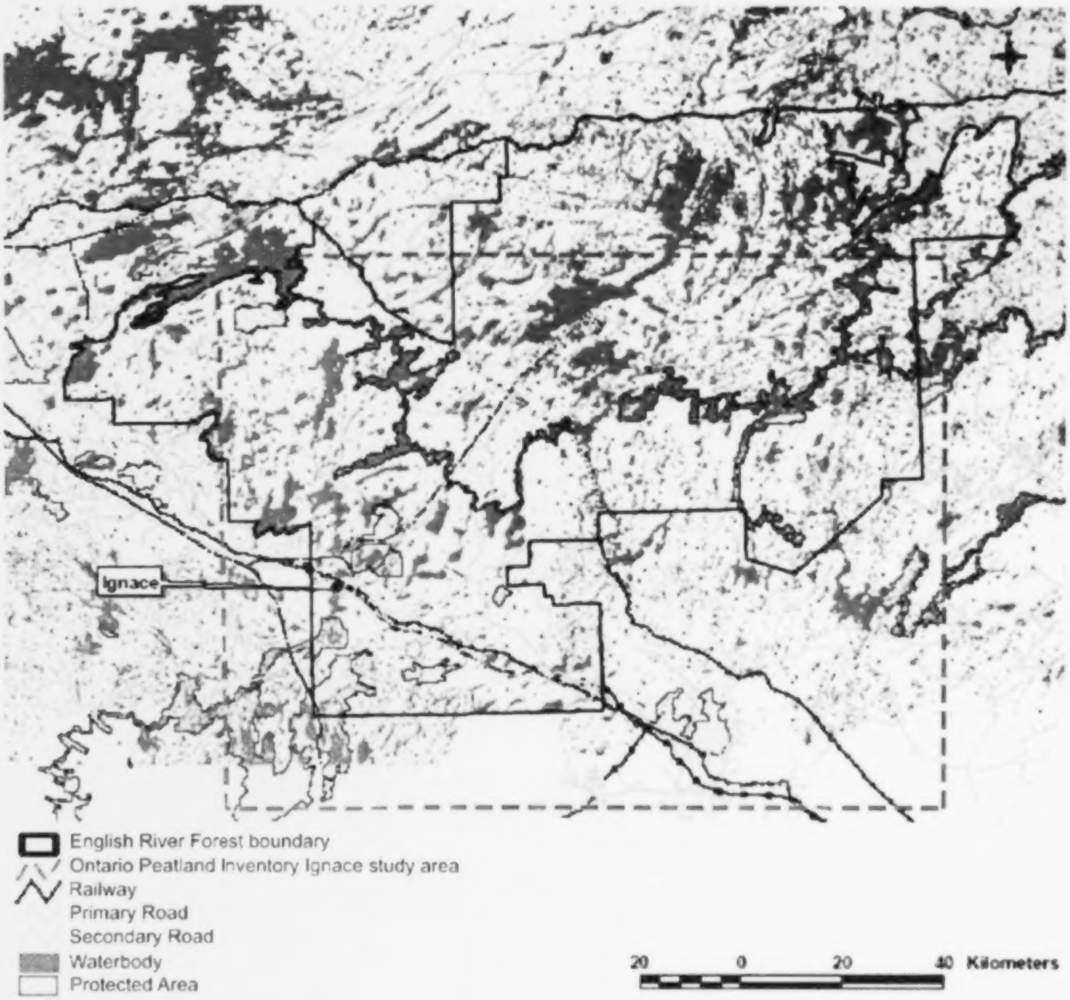
Assessed wetlands on the Dog-River Matawin Forest (Harris and Foster 2005)



Wetlands labelled in black scored provincially significant on both models; those labelled in purple scored significant on one model only, and those labelled in red were not provincially significant. Text boxes provide the report number for wetlands surveyed by the Ontario Peatland Inventory (Riley and Michaud 1987).

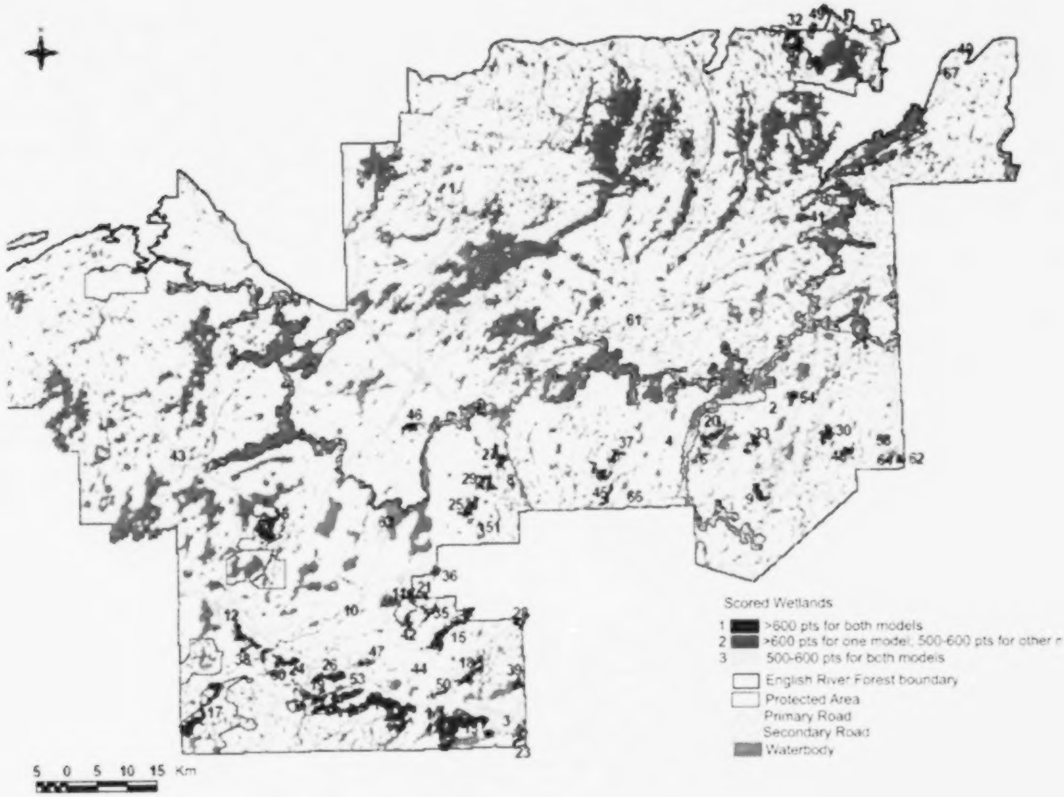
Appendix 6:

General location of the English River Forest Management Unit in northwestern Ontario (Harris and Foster 2004)



Appendix 7:

Estimated evaluation scores for wetlands >100 ha in the English River Forest (Harris and Foster 2004)



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